R·E

PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS.

R. E.

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INTRODUCTION.

The Papers in the present volume will, I hope, be found in no way deficient in interest as compared with those of the earlier volumes. Those which treat of subjects more exclusively connected with the Military Branch of our Profession will be read with interest,—while the second portion of the Paper on Railways, which completes that branch of the subject as far as relates to the Formation of the Roadway, will, I think, be a most valuable contribution to our stock of professional information. This Paper is of course confined to the mere mechanical construction of a railway; but a wide field of inquiry is opened to us when we come to consider the effect which these new and rapid means of communication may have upon the whole system of warfare. Great changes will in all probability be required to place the system of passive defence—if I may so term it—at all upon an equality with what it was before the introduction of steam; and we should as Officers carefully consider what these changes should be, and be prepared to carry them out in the most effective manner when required.

On the other hand, we must not forget that the system of active defence will benefit most materially by the introduction of the great net-work of railways now intersecting the country, which will enable the whole force of the kingdom to be concentrated in a few days, I may even say hours, at any given point.

I have appended to this volume a General Index to the first seven volumes, which, although it adds to the bulk, will be found so valuable for reference as fully to compensate for this inconvenience.

W. D.

PROFESSIONAL PAPERS.

I.—*Observations upon the Destruction of the Bridges at Banagher and Rooskey, on the River Shannon. By Lieutenant-Colonel* HARRY JONES, *R.E.*

DESTRUCTION OF BANAGHER BRIDGE, 1843.

THIS bridge was composed of seventeen semicircular arches, having very thick piers, built with rubble masonry of a very inferior description. As the materials of the bridge would be very serviceable for the formation of a dam, which was required to be formed adjacent to where it stood, it was decided to throw down the entire bridge by gunpowder: an experiment was then made, by placing 50 lbs. of powder, calculated according to General Pasley's rule, $\frac{R}{10}$, in one of the piers: this charge, when fired, produced the desired effect. The remaining alternate piers were then loaded with 50 lbs. each; shafts were sunk in the roadway to the depth of 8 feet; and a chamber formed (*a*, fig. 3) in which the powder was placed, and the tamping was formed by the materials taken out in sinking the shafts. Two pieces of Beckford's patent fuze were used for firing each charge. Men were stationed at each shaft, to light the fuzes upon the signal being given. The explosions were nearly simultaneous; the entire bridge appeared to be raised a few feet, and then fell a confused mass of stones, with the exception of a small portion of two piers, which remained standing; no stones were thrown to any distance, and the demolition might be considered perfect. The patent fuze answered admirably, as it has in all cases where it has been employed on the Shannon, and other places where I have had opportunities of using it.

Plate I.

The double train was put in by the direction of the resident-engineer, who, being fearful of a failure, thought it best to have "two strings to his bow."

Such a precaution was needless; for however much bruised by the tamping, or crushed by a stone, it seldom fails of igniting the charge to which it is attached.

HARRY D. JONES,
Lieut.-Colonel, Royal Engineers.

Shannon Office,
Dublin, 16th December, 1844.

DESTRUCTION OF ROOSKEY BRIDGE, 1844.

During the progress of the works carrying on under the direction of the Commissioners for the improvement of the Shannon Navigation,[1] it having been found necessary to remove the bridge at Rooskey, in order that a new one might be erected nearly upon the same site, it was considered to be a favourable opportunity for making experiments as to the charges necessary for destroying it, or similar works, by gunpowder; and further, by using the voltaic battery to fire the charges simultaneously.

Captain Larcom, R.E., permitted the voltaic battery from the Ordnance Survey Office to be sent to Rooskey, under the charge of Mr. Dalgleish, who was to make all the necessary arrangements respecting the conducting-wires for firing the charges, he having been employed under Captain Larcom at the several experiments that officer had made with the voltaic battery in the Phœnix Park.

The bridge at Rooskey was erected in the year 1756, and consisted of one large arch in the centre, and four smaller ones on each side of it, making a total of nine arches: they were built with rubble masonry, set in good mortar; the stones only forming the coins of the arches were hammer-dressed with 7-inch beds; two walls set in mortar crossed the spandrils; the interior of the piers and spandrils were filled with loose earth and stones; large stones appeared to have been dropped into the bed of the river as a foundation, upon which the piers were built.

lat· II The dimensions will be found marked on the plan and elevation, figs. 1 and 2, by which it will be perceived that the arches were nearly uniformly equal on each side of the centre.

In destroying the bridge, it was very important that no injury should be
a e II. done to the temporary wooden one (M, figs. 1, 3, 4) that had been erected by the

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[1] Commissioners, Major-General Sir J. F. Burgoyne, K.C.B., Lieut.-Colonel Harry D. Jones, R.E., and Richard Griffith, Esq., C.E.

contractor; as if injured, and the communication stopped, great inconvenience would ensue to the public, there being no bridge across the river Shannon nearer than nine miles above, and ten miles below Rooskey: it was therefore necessary to use the smallest charges that would be likely to produce simple demolition.

As this appeared to be a favourable opportunity to ascertain the effects that would be produced by charges calculated according to Major-General Sir John Burgoyne's formula, $\frac{L R^3}{32}$, it was decided to try charges so calculated in piers G and H, before any of the other piers were loaded.

Shafts were sunk in the centre of the roadway, to the depth of about 2 feet above the spring course of the arches, and in the small piers chambers were run 5 feet on each side of the shaft, in the direction of the longitudinal axis of the pier; the charges were placed at the extremity of the chambers, and were connected by powder, placed in a wooden trough, (*a*, fig. 8,) in which was inserted the igniting cartridge, intermediate between the charges, (*b*, fig. 7.) Where only one charge was used, the igniting cartridge was placed in the centre of the charge; the stones and earth removed in sinking the shafts were used for tamping.

Plate I.

The quantity of powder calculated for H, where the line of least resistance was 10 feet, was equal to $\frac{10^3}{32}$, or 31 ℔s.; and 1 ℔. 5½ oz. for each chamber in G, where the lines of least resistance were 3 ft. 3 in., and the chambers 5½ feet apart: the effect was in H, to crack the pier, as shown in Plate II. fig. 3, and to shatter a part of the parapet immediately over it: G produced no visible effect; it was at first doubtful whether the charge had exploded; however, after a short period smoke was perceived issuing from among the loose stones forming the foundation.[2]

The above charges having failed to produce the desired effect, it was then decided to load the remaining small piers with charges 25 ℔s. each, divided into two charges of 12½ ℔s. for each chamber, and the large pier A with 50 ℔s. in a single charge: these charges were determined by the experience obtained in the destruction of Banagher bridge, when the mass to be thrown down was nearly equal to that pier, A.

It may be here stated, the charge in pier B was accidentally fired, in consequence of the contractor's man, who had been assisting in the preparation of, and arranging the wooden casings for, the protection of the cartridge wires, having, without authority, placed the end of the wires from the voltaic battery with that from the charge in the mercury cups, unknown to the party who were adjusting the wires at the batteries, previous to the final arrangement on the bridge: the connection being completed, an explosion took place, the effect of which was to throw down a few stones from the right side of pier B, immediately opposite to the chambers, and caused a large crack in the roadway.

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[2] It is necessary to observe that the piers were all laid dry by the dams which had been formed to enable the contractor to deepen the bed of the river by excavation, (*a*, *a*, Plate III.)

The remaining charges were fired simultaneously, and the effect was to throw down pier A, with the two adjoining arches, (see fig. 3,) and to crack the roadway of the remaining part of the bridge, as shown on plan. Plate II.

It was then determined to reload the standing piers with 20 lbs. in each chamber, but this could only be accomplished in pier G; the chambers of the others could not be opened without danger, from the spandril walls being much cracked: the charges of 40 lbs. were therefore placed at the bottom of the shafts; the tamping was somewhat better than before, as the powder was not divided into two portions, but formed one charge.

The effects were to throw down the remaining portion of the bridge, with the exception of half the arch in the direction of the length between piers C and D, (fig. 4,) which fell on the following day.

The voltaic batteries used on this occasion were the combination of Professor Graves; they consist of twenty-four cells, the platinum plates 6 inches by 3½, with zinc on each side: the batteries, under the immediate direction of Mr. Dalgleish, were placed at 150 feet from the bridge, and the wires arranged, as shown in Plate III. The main conductors were detached from those leading to the charges, to prevent them from being dragged away, or injured by the effects of the explosion. The connections were perfected by the insertion of their ends in small cups containing mercury, placed on the roadway of the bridge, near each shaft.

The firing of the charges with the voltaic battery was instantaneous. One failure occurred, which was afterwards ascertained to have been caused by the wire leading to the charge having been disconnected in tamping.

It should be borne in mind, that the use of the voltaic battery on this occasion was not under the supposition that it was better suited for the purpose of firing the charges used for the destruction of bridges, than in the ordinary way adopted in campaigning, but to afford another experiment with respect to the employment of the voltaic battery, in addition to those previously made by Captain Larcom, R.E., the results of which, it is understood, that officer will communicate for the benefit of the corps.

Details relating to the operations of the voltaic battery, therefore, are not inserted in this Paper.

The powder used was the common blasting powder from the Ballincollig mills, which is large-grained and highly glazed. Strength proved by the eprouvette gun, as compared with the Government L. G. powder, was 1·5° less, the former giving 21°, and the powder used at Rooskey 19·5°.

The results with equal charges proving so very different, it is important to endeavour to explain the causes for such difference. The only way in which it can reasonably be accounted for, would appear to be this,—that the interior of the piers being filled with loose rubble stones, the effects of the powder, when ignited, were greater or less in proportion to the greater or less compactness of the materials: where loose, and large interstices existed, the gas rushed through the openings between the stones; and when it reached the arch, or facing of the pier, which was set in mortar, it had lost its power by expansion, and was unable to force out the masonry composing the piers. It must on these premises be inferred that the piers D, E, F, G, were built much more compactly than the piers A, B, C, which may be accounted for from the circumstance that the repairs to the bridge were performed by different counties: had the bridge been formed of good substantial masonry, it may be deemed certain that the quantity of powder employed would have been too small, as the charge in pier B, (fig. 2,) when fired accidentally, did not bring down the arch; and the demolition which took place may be attributed to the several charges having been fired simultaneously. By the concussion the whole fabric was shaken; the weaker parts, losing their cohesion, fell.

In conclusion, I would observe, from the experience gained during the Peninsular war, the masonry of the bridges at Valladolid and Tordesillos, which were blown up in 1812, on the retreat of the army from Burgos, was as hard, and nearly as compact as rock; and from what I have seen of the bridges on the Shannon, which have been taken down during our operations, in my opinion there is no calculation of a charge of powder for the destruction of bridges which can be adopted with certainty: so much depends upon the description of masonry, the quality of the mortar, the mode of construction, and the nature of the arch, as well as the climate, that the same quantity of powder upon piers of equal dimensions would not produce equal effects. It therefore behoves the engineer to study well the construction of the bridge,—to ascertain the nature of the interior, or filling of the piers, the quality of the masonry, and the time, as well as means at command, for its destruction.

The French engineers' rule for destroying bridges by gunpowder is as follows:

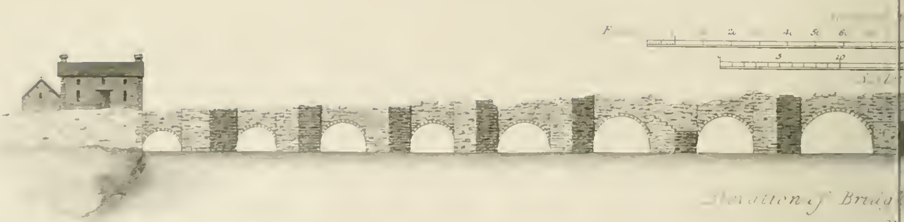
(Translation.)—" If the piers are of masonry, and ($1{\cdot}30^m$ to $1{\cdot}60^m$) 4 ft. 2 in. to 5 ft. 2 in. thick, chambers are formed in one of them, in which are placed (50 to 60 kilogrammes) 134 to 160 ℔s. of powder, (English weight.)

" If the pier is (2^m to 3^m) 6 ft. 6 in. to 9 ft. 10 in. thick, the chambers ought to be loaded with (150 to 200 kilogrammes) 402 to 536 ℔s. of powder, (English weight.") The quantity of powder thus recommended to be used, so much exceeds the quantities that English engineers have ever employed in the demolition of bridges, or that were ever used in the destruction of the numerous bridges during the Peninsular war, under the Duke of Wellington, that those quantities ought not to be regarded as data for future operations of a similar nature, excepting as making certain of the destruction of a bridge by employing the very large charges recommended to be used.

At the same time, under circumstances similar to the destruction of the bridges on the Shannon, where it was necessary to guard against doing injury to the houses in the immediate neighbourhood of the bridge, and most important that the temporary wooden bridges erected by the contractors, and very near, should not be damaged, it will be advisable to use reduced quantities of powder, placed in two distinct charges, it being better that there should be a chance of the necessity for a second loading than that the inhabitants should suffer, and more particularly as there is plenty of time for reloading in cases of failure. On the contrary, on service, in the presence of an enemy, the engineer intrusted with the destruction of the bridge must make sure of his object, by employing a sufficiently large charge of powder, which he is recommended to place in one mass, in preference to a division of the charge: the effects will be greater, and there will be less labour in the previous operation of sinking into the masonry. As there still remain three or four other bridges to be taken down, further experiments will be made, and the results communicated.

HARRY D. JONES,
Lieut.-Colonel, Royal Engineers.

Shannon Office,
Dublin, 16th December, 1844.



Elevation of Bridg

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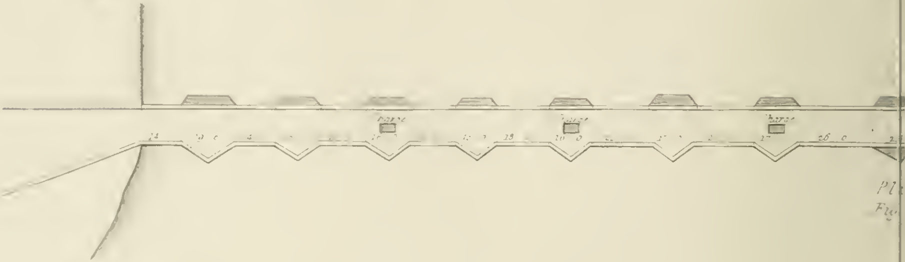
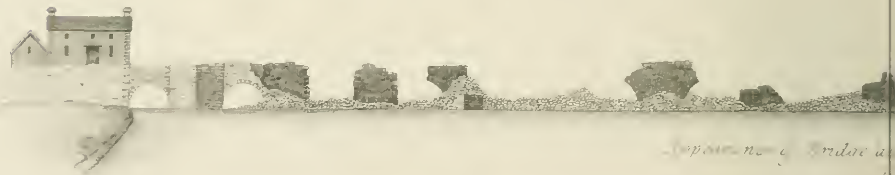
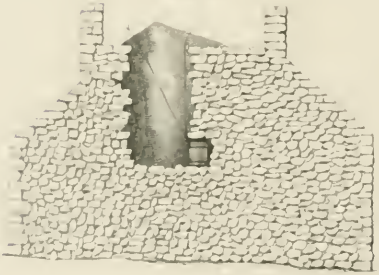


Pl

Fig



Appearance of Bridge a

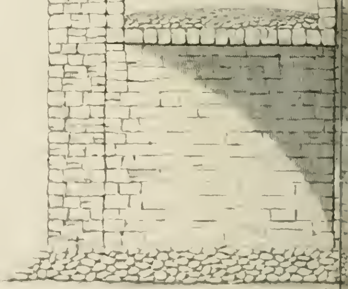


Transverse Section on line A B

Fig 4

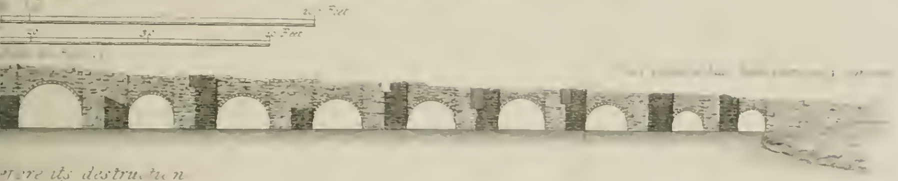
Transverse Section on A B Fig

Fig 5



BANAGHER BRIDGE.

Blown up by Gunpowder in the Year 184



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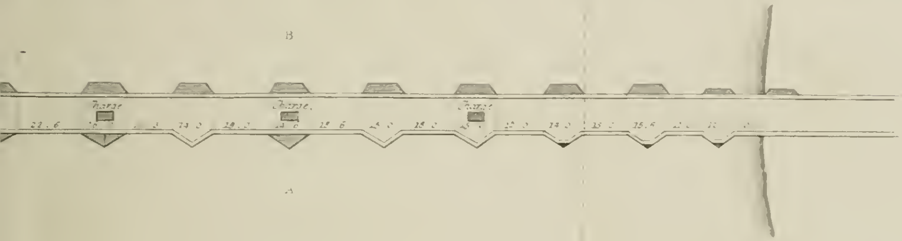
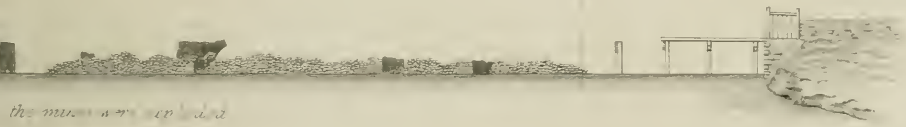


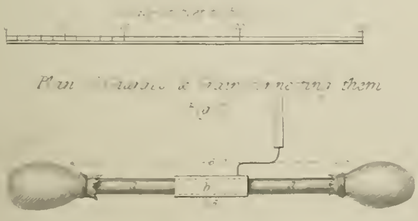


the mines were exploded

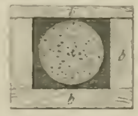
ROOSKEY BRIDGE

Details of Explosion

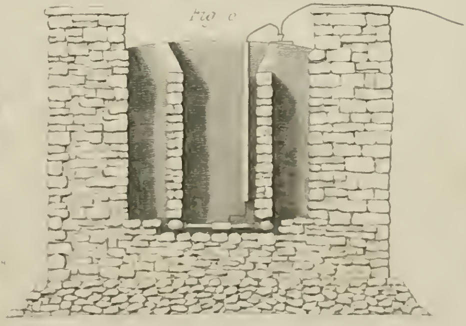
Plan of Charges & Train connecting them



Section through the Connecting ... full size



Section of a Pier
shewing Charges & Conducting Wire



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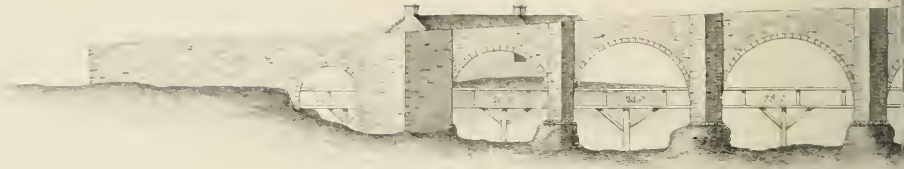
ROOSKEY

Blowing up with Gunpow

Elevation of Brida
Fig



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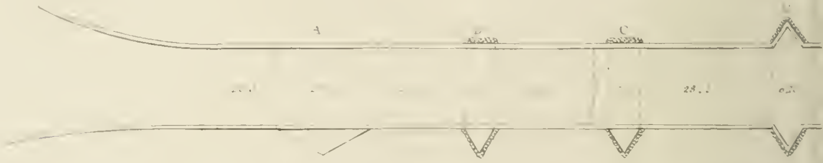
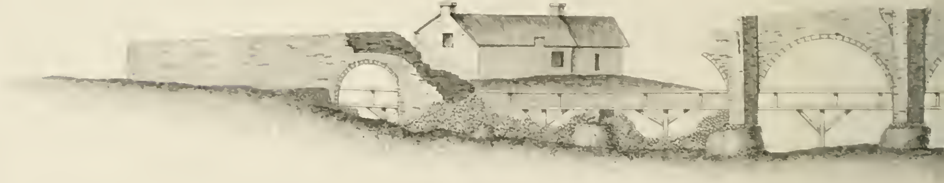
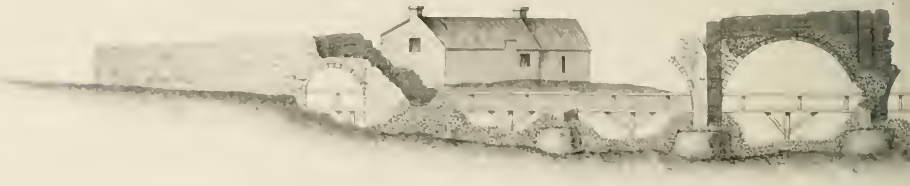


Elevation after
Fig



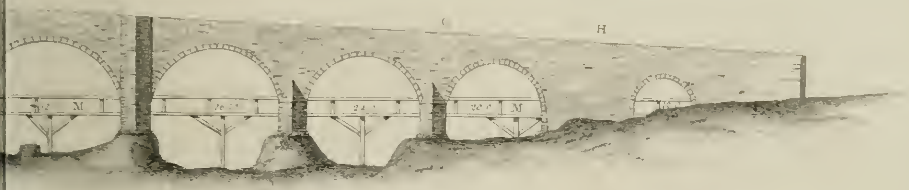
Elevation of
Fig

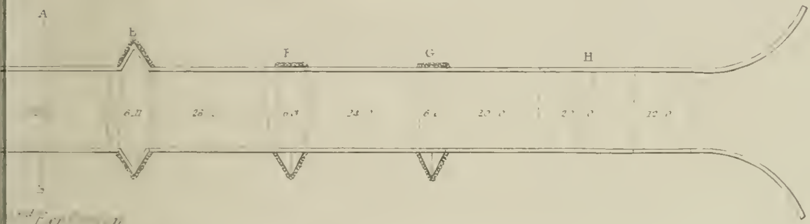


BRIDGE,

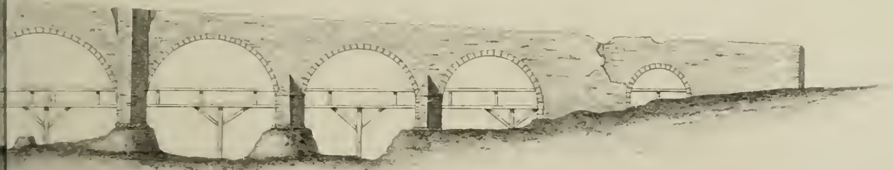
in the Year 1811

ore its destruction.

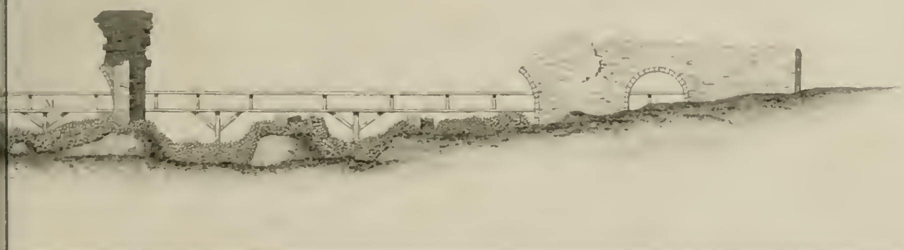




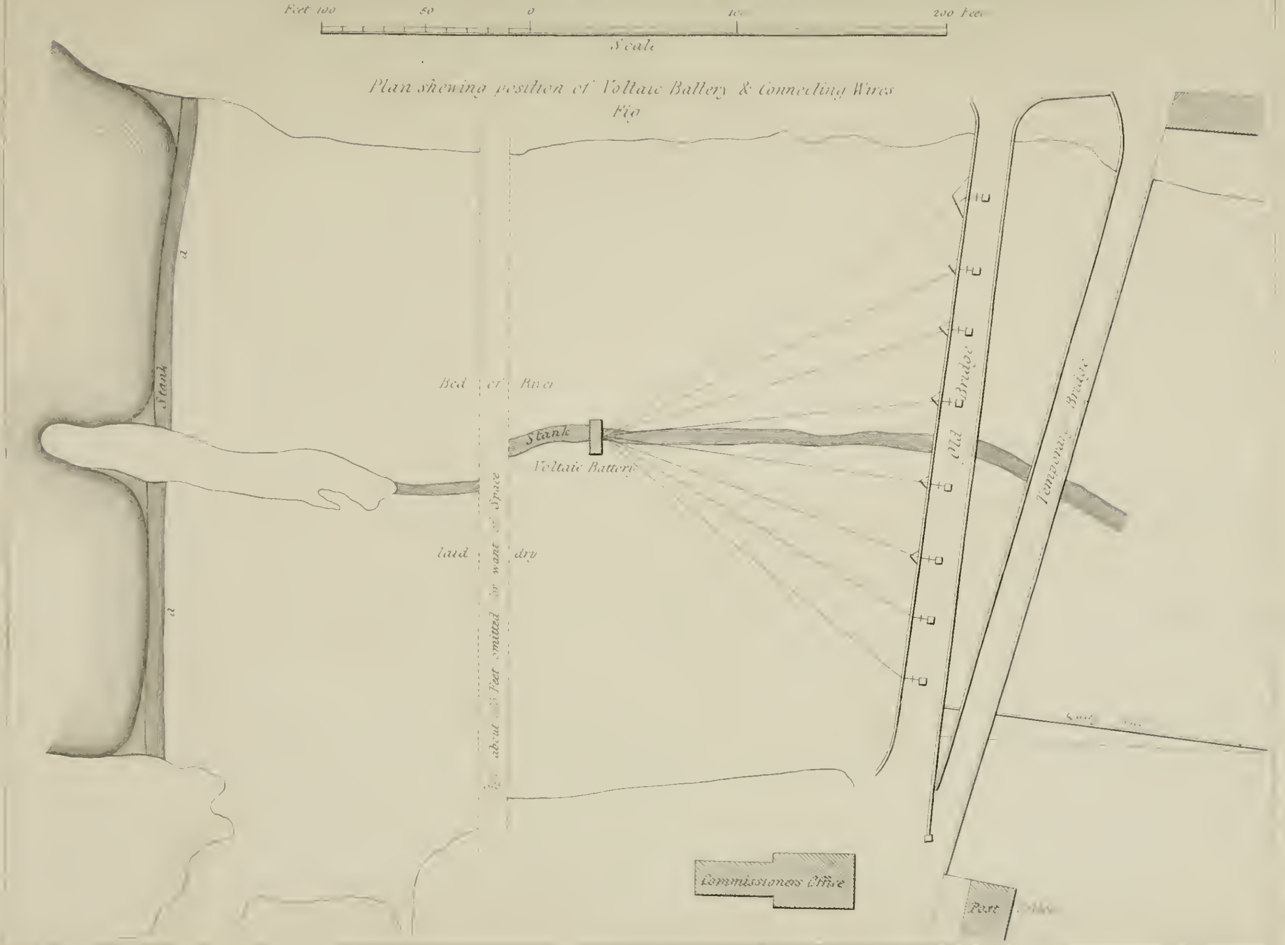
Explosion.



3rd Explosion



ROOSKEY BRIDGE



Plan shewing position of Voltaic Battery & Connecting Wires

Fig.

II.—*Notes on Platforms.* *By Captain* PORTLOCK, *R. E., F.R.S., &c.*

IT is remarkable, that the length of a platform, when considered in relation to the gun to be placed upon it, and to the material of which it is to be constructed, depends at present upon such imperfect data, that it can be considered satisfactorily determined only in a very limited number of cases; and yet it is an element of construction equally required in attack and defence.

I have been led to make these remarks from the following circumstances:

In the fortress of Corfu, including its dependency Vido, the gun and mortar platforms have been constructed of one material, namely, the white Mediterranean limestone, a rock which possesses a striking uniformity of character through a considerable geological range, and possesses, in a high degree, the physical qualities of hardness and brittleness; but, though the material used has been the same, there is found a striking diversity in the lengths of the platforms intended to be used even for cannon of the same calibre, and applicable to the same purposes. Thus, at Vido, platforms for heavy 24-pounders have been laid at 12 feet, and at Corfu, at 13, 14, 15, and 16 feet, the slope also varying from 1″ in 3′ to 1″ in 2′. Some of the Corfu platforms were originally estimated at 15 and 16 feet, but, from motives of economy, were reduced in construction to 13 and 14 feet; and it may be presumed that a similar motive induced the adoption of 12 feet at Vido, for though the estimates do not detail the length of the platforms, the plan of the keep shows by scale a length of 16 feet.

For the future this uncertainty has, at this station, been removed by the Commanding Royal Engineer, Lieut.-Colonel Thomson, who has directed that stone platforms for heavy 24-pounders shall henceforth be laid at 16 feet, with a slope of half an inch to a foot.

The insufficiency of the Vido platforms was practically demonstrated in the year 1842, when one of the guns having been fired, it recoiled entirely over the platform, and the carriage was, in consequence, broken. This untoward result might, without doubt, have been guarded against, as suggested by the Director-General of Artillery, "by sanding the platform, or clogging the trucks by a handspike;" but though such expedients may be properly applicable to unexpected contingencies, they ought not to be rendered necessary throughout a fortress by a generally inadequate length of platform.

The result of the Vido experiment having been represented by Lieut.-Colonel H. W. Gordon, commanding Royal Artillery, to the Commanding Engineer, Lieut.-Colonel Thomson suggested that a series of experiments should be made, to ascertain by direct practice the amount of deficiency in length of the platforms; and this proposition having been submitted by Lieut.-Colonel H. W. Gordon to his Excellency Lord Seaton, Lieutenant-General commanding, it received his immediate sanction, and was carried into effect.

1st Trial, Oct. 6th, 1843.—Four rounds fired from a 24-pounder, mounted on an iron garrison carriage, on a stone platform, in the Savergnano bastion. Length of platform 13 feet, slope 7½ inches; stone very rough. The platform was temporarily lengthened by wooden skidding. Charge, 8 lbs. of powder with round shot.

No. of rounds.	Elevation.		Distance of centre of hind axle from the foot of parapet.
1	P. B. (wad over the shot)		13′ 5″
2	1°	,,	13′ 2″
3	2°	,,	12′ 11″
4	3°	,,	14′ 2″

The actual recoil therefore (after deducting the distance from the base of the parapet to the hind axle) in each round was respectively 8′ 5½″, 8′ 2½″, 7′ 11½″, and 9′ 2½″, giving an average of 8′ 5½″, or less than the average of Woolwich practice, to be hereafter noticed.

2nd Trial, October 13th, 1843.—Eight rounds fired from a 24-pounder, mounted on a wood garrison carriage, on a stone platform, in the south battery at Vido. Length of platform 12′ 1″, slope 4 inches; stone evenly dressed. The platform temporarily lengthened as before. Charge 8 lbs. of powder with a round shot.

No. of rounds.	Elevation.	Distance of centre of hind axle from the foot of parapet.
1	4°	14′ 10″
2	1° Depⁿ. (wad over shot)	13′ 10½″
3	3° El.	14′ 11½″
4	P. B. (wad over shot)	13′ 10¾″
5	5° El.	14′ 1½″
6	3°	15′ 0″
7	2°	12′ 9½″
8	1° (wad over shot)	14′ 5″

The actual recoil therefore in each round was respectively 9′ 8″, 8′ 8½″, 9′ 9½″, 8′ 8¾″, 8′ 11½″, 9′ 10″, 7′ 7½″, 9′ 3″, giving an average of 9′ 0¾″, or only 3¾ inches more than the Woolwich average; the maximum recoil on the sixth round, 9′ 10″, being only 2½ inches more than the maximum recoil of the Woolwich practice.

The experiments here detailed are certainly not sufficiently extensive to determine the case in all its bearings; but such as they are, the results were officially communicated by Lieut.-Colonel H. W. Gordon to the Director-General of Artillery, by whom the recoil was considered 'inordinate,' though certainly, as shown by the above comparison, it was not at variance with the Woolwich experiments; and, considering the much higher rise or slope of the Woolwich platforms, it may be even considered less than the Woolwich recoil.

The Director-General observes, "On referring to the records of practice carried on at Woolwich in 1810, from 24-pounder guns, with the service charge, mounted on iron carriages, it appears the recoil in no case exceeded 9′ 7½″, and that the average recoil upon fifty rounds was 8′ 9″. The platforms were of wood, 15 feet long, with an inclination of 8½ inches."

In the instance of the greater recoil here mentioned, the centre of the rear axle was 14′.7″ from the front of the platform or foot of the parapet, and only 5 inches from the rear of the platform, over which the hind truck projected 4½ inches: in the average recoil, the centre of the rear axle was 13′ 8½″ from the front, and 1′ 3½″ from the rear of the platform. It is evident, therefore, that 15 feet can be considered only barely sufficient, as deduced from the Woolwich and first Corfu set of trials,—the slope being, at least, 7½ inches, and 16 feet, as deduced from the second Corfu set, with a slope of 5½ inches.

These experiments, then, satisfactorily limit a platform for a heavy 24-pounder, to be fired with a full service charge, to lengths between 15 and 16 feet (with a rise of half an inch to a foot); and it is doubtless to the want of such detailed experiments that some diversity of opinion has hitherto existed amongst military writers on so simple a subject.

Vauban ('Attaque et Defence,' 1737,) describes platforms varying from 19 feet to 21 feet 3 inches (English.)

Theodore Durtubie, General of Brigade in the French Artillery, ('Manuel de l'Artilleur,' 1794,) gives to wooden platforms a length of 14′ 11″ (English.)

Carnot ('Defence des Places Fortes,' second edition, 1811,) states the recoil at 10′ 8″, English, so that the least possible length of a platform would be 10′ 8″+4′ 4″ (the distance between the axles of the trucks)+10″ (the half-diameter of the fore truck)=15′ 10″; or, allowing a very moderate space behind the rear truck, the platform could scarcely be constructed less than 17 feet.

C. W. Pasley, Major-General, Royal Engineers, F.R.S., ('Course of Elementary Fortification,' 1822,) gives to his new siege-gun platform a length of 15 feet, the slope being half an inch to a foot, and the material wood.

J. S. Macaulay, Captain, Royal Engineers, ('Treatise on Field Fortification,' 1834,) recommends a platform 17 feet long, with a slope of 6 inches, for heavy artillery; and one of 15 feet for field guns.

Captain and Adjutant Griffiths, Royal Artillery, ('Artillerist's Manual,' 1839,) adopts, for wooden platforms, a length of 15 feet, which number is quoted with approval by Hector Straith, Captain, H. P., unattached. ('Treatise on Fortification,' third edition, 1841.)

Let these results be now tested theoretically.

The weight of a 24-pounder, with wooden carriage, is 7135 ℔s.; the ratio, therefore, in weight of the shot to the gun and carriage is as 1 to 297. The weight of a 24-pounder, with iron carriage, is 7868 ℔s.; and the ratio in weight of the shot to the gun and carriage is as 1 to 327·8. If, therefore, the initial velocity of the shot with the full service charge be assumed (as stated by Dr. Olinthus Gregory, in the second edition of Hutton,) to be 1600 feet per second, that of the recoil will, with a wooden carriage, be 5·38,—with an iron carriage, 4·88; the first of which is the velocity which would be acquired by falling through 5·4 inches, and the second by falling through 4·4 inches; and the spaces on the inclined plane of the platform passed over by the gun in its recoil, according to one or the other of these heights, will be, (omitting for the present the consideration of friction,)

With rise of 1 inch in 3 feet,	and wooden carriage . . .	16·2 feet.
,, ,,	and iron carriage	13·2 ,,
,, 1 inch in 2 feet,	and wooden carriage . . .	10·8 ,,
,, ,,	and iron carriage	8·8 ,,
,, $\frac{3}{4}$ inch in 1 foot,	and wooden carriage . . .	7·2 ,,
,, ·8 inch in 1 foot,	and wooden carriage . . .	5·4 ,,
,, 1 inch in 1 foot,	and wooden carriage . . .	5·4 ,,
,, ,,	and iron carriage	4·4 ,,

Comparing these results, in which friction has not as yet been introduced, with the two preceding sets of experiments, it is remarkable that the average recoil on the Vido platform, having a rise of 1 inch in 3 feet, was only $9'\ 0\frac{3}{4}''$, and must therefore have been diminished by the friction of the trucks on the rough boards used for elongating the platform.

In the Savorgnano experiment, the rise being 1 inch in 2 feet, the average recoil was $8'\ 5\frac{1}{2}''=8\cdot46$, or very little less than the distance 8·8 feet, which corresponds to the theoretic rise of the centre of gravity, independent of friction.

The initial velocity will be diminished by several retarding forces: as, 1st, The resistance of the air, which with so small a velocity as either 4·88 or 5·38 feet per second, ($3\frac{1}{3}$ or $3\frac{2}{3}$ miles per hour,) may be neglected. 2nd. Loss of power, by absorption of force in the compression, and change of form of the bearing parts, both of the carriage and of the platform, under the shock of firing. This, however, when the platforms are well made and of good materials, may be left out of consideration. 3rd. Friction at the axle of the trucks, and between the face of the truck and platform; but of these it is only necessary to notice the first, as the second can only sensibly affect the results when the platform is formed of a very uneven, or of a highly-yielding material.

As the gun moves from a state of rest, and little attention is paid to the condition of the axles, the constant of friction may be assumed at ·185 of the pressure, or 1320 lbs. with a wooden, and $1455\frac{1}{2}$ lbs. with an iron carriage.

The actual retarding effect of this amount of friction will be diminished in the proportion of the diameter of the truck to that of the axle. In the wooden carriages, the fore and rear axles and trucks are of unequal diameters, but we may take the mean, or average diameter of each; viz., 1·46 feet of the truck, and ·552 of the axle,—the proportion of the one to the other being 2·6 to 1.

In the iron carriage, the diameter of the truck is 1·52 feet, and that of the axle ·333,—the proportion being as 4·54 to 1.

With these proportions, the additional retarding weight corresponding to the friction of the wooden carriage is 508 ℔s. nearly, and that of the iron carriage 320 ℔s.: adding their weights to the gross weight, we have 7643 ℔s. as the moving weight of the wooden carriage, and 8188 ℔s. as that of the iron carriage, and the initial velocities of recoil become 5·02 per second for the wooden, and 4·69 for the iron carriage—velocities corresponding to a vertical rise of 4·68 inches in the wooden, and 4·08 in the iron, or to a space on the plane of 9′ 4″ and 8′ 2″ respectively, when the slope of the platform is $\frac{1}{2}$ inch to a foot, or 14′ and 12′ 3″ when it is 1 inch to 3 feet.

Comparing these theoretic results with those of actual experiments, it appears, that with the iron carriage and a platform having a slope of $\frac{1}{2}$ inch to a foot, as in the Savorgnano experiment, the actual average recoil was 8·46 feet, the theoretic 8·17, the difference being only 0·29; whilst with the wooden carriage and slope of 1 inch to 3 feet, as in the Vido experiment, the actual average recoil was 9·1 feet nearly, the theoretic 14; and as so very great an excess of the practical over the theoretic recoil does not occur in any other experiment, the retardation of the recoil of the wooden carriage must be ascribed to extraneous causes. One of these has been previously mentioned, namely, the rough mode of adding to the length of the Vido platform; but it is possible, that the rough construction of the axle itself of the wooden carriage may also retard, by augmenting the constant of friction. The axle is not solid iron, but is of wood sheeted on the under or bearing side with plate iron; and it is highly probable that the friction is much increased by this rude contrivance.

The result, however, fully confirms the propriety of the lengths of platforms adopted for a slope of $\frac{1}{2}$ inch to a foot.

In the preceding observations, it has been presumed that there is no want of space, and that the platforms may be laid, without inconvenience from that cause, of the required length; but it may happen that the space is limited, and that it is desirable therefore to use shorter platforms. Assuming the preceding results to be correct, the lengths of such platforms may be thus estimated.

Vertical rise of centre of gravity equivalent to the initial velocity of recoil, 4·68 inches with wooden carriage, 4·08 inches with iron carriage. Hence the following dimensions would be required:

Slope of platform.	Recoil on inclined plane.	Distance of rear axle from parapet.	Least possible length.	Least admissible length.
$\frac{1}{3}$ in. to a foot.	14·18	5·0 in.	19·18	20·0
$\frac{1}{2}$,,	9·36	5·0	14·36	15·6
$\frac{3}{4}$,,	6·24	5·0	11·24	12·6
·8 ,,	5·85	5·0	10·85	12·0
1 ,,	4·68	5·0	9·68	11·6

These remarks having been submitted to the Commanding Royal Engineer, one of the platforms in the Savorgnano bastion was, by his desire, altered so as to conform as nearly as possible to the above rule.

This platform is 13 feet long, and the slope is 10½ inches.

With his usual anxious zeal to aid in any experiments calculated to introduce certainty or improvement into the practical part of his profession, Lieut.-Colonel H. W. Gordon, commanding Royal Artillery, at once offered to request the sanction of His Excellency Lord Seaton to some experimental practice on this platform, of which the following is the result:

June 15*th*, 1844.—10 *hours* A. M.

Platform of stone, dressed, 13 feet long. Slope 10½ inches. Charge 8 lbs. with round shot.

No. of rounds.	Elevation.	Distance of centre of hind axle from the foot of parapet.
1	Point B.	11′ 4½″
2	Ditto.	11′ 4½″
3	3° E^{n}.	10′ 11¾″
4	2° E^{n}.	11′ 2″
5	1° D^{n}. (wad over shot)	11′ 4″

Hence, deducting the distance of the axle of the rear truck, before fire, from the parapet, or 4′ 11½″, the gun having been run out to its utmost limit, the actual recoil in each was 6′ 4″, 6′ 4″, 5′ 11¼″, 6′ 1½″, 6′ 3½″. Hence the centre of gravity of the gun and carriage rose, on an average, 5·1 inches nearly, in the space of 6′ 2½″; the theoretic recoil, as shown by the preceding Table, being 5·85, or only 0·36 inches less than the actual recoil.

The effect of the fire upon the platform, constructed not more than one month, gave also one other valuable hint, namely, the necessity of strengthening the platform in the line of the hind trucks, where the shock is first received. The stones should here be superficially large, in order to spread the shock over a wider space, and deep, in order to prevent splitting: they ought, as a rule, to be at least cubes of about 2 feet; but it would be preferable to make them superficially 3 feet by 2, the larger axis being in the length of the platform.

No stone platform having been prepared with the slope adapted to 12 feet, Lieut.-Colonel H. W. Gordon fired three rounds from a gun on a traversing platform, the slope of which is a little more than one inch to a foot, or a little more than the slope adapted to a length of 12 feet.

No. of rounds.	Elevation.	Distance of centre of rear axle from the front of platform.
1	P. B.	10′ 2″
2	2° E^{n}.	10′ 5″
3	3° E^{n}.	10′ 4½″

And the actual amount of recoil was 5′ 1½″, 5′ 4½″, 5′ 4″.

Practically, therefore, it appears, that with a stone platform, no slope less than ½ inch to a foot should be adopted; and that with that slope, 16 feet is a sufficient length;—with ¾ inch to a foot, 13 feet;—with 1 inch to a foot, 12 feet; as it is desirable to keep the hind truck well on the platform.

In using these data it must, however, be kept in mind, that as the slope increases, the shock on the platform increases also; and that it becomes necessary, as before stated, to add to the solidity of the platform at the points which first receive the shock, namely, in the line of the two rear trucks.

In addition to the principal object of ascertaining the amount of recoil on a platform constructed with a rise of 1 inch in one foot, it was the wish of Lieut.-Colonel H. W. Gordon to test the reality of supposed danger of firing on traversing platforms, which had induced an order, that in firing the trucks should be replaced by wooden chocks. The recoil itself appears to be quite easy, and without any tendency to throw the gun laterally from the platform; whilst it is evident that, as the great rise of the centre of gravity in a small horizontal space, viz., 5 inches in 5 feet, is sufficient to extinguish the initial velocity of recoil, nothing should be done to add to the shock on the platform, by attempting further to diminish the recoil.

When, however, the gun has been discharged and put in motion, in order to be run up, it is liable to acquire velocity, and to strike violently against the front stops of the platform; and here there might be a danger either of injury to the platform, or to the gun. Lieut.-Colonel H. W. Gordon guarded against this evil, by placing wads on the front stops; and so great was the force with which they were struck, that they were quite flattened by the shock. These circumstances suggest,—first, a modification of the form of the platform, which should be made in such a manner as to allow the fore trucks to rise upwards gradually on approaching the front, and thus to extinguish the acquired velocity without a shock.

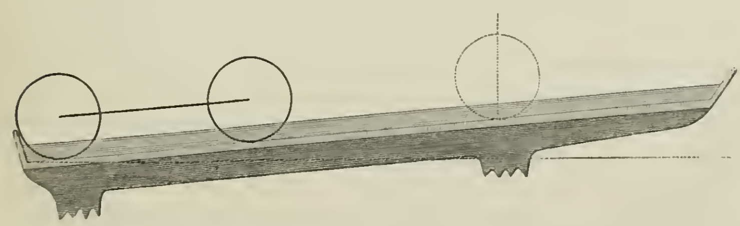
2nd. A diminution of the length of the platform, which being now 15 feet, is at least two feet longer than can be necessary. This excess, by increasing the radius of the traversing curve in rear, is frequently the cause of much inconvenience, and especially in cases where it may be desirable to traverse the gun all round the circle, as is actually the case in the salient of the right bastion of the scarpone horn-work. When reduced to 13 feet, the platform will traverse on a centre pivot, without inconvenience, through the whole circle.

The advantage of increased leverage is not sufficient to compensate for the disadvantage of a restricted traversing curve; and even in this sense, power might be more advantageously applied, were there a contrivance for shipping on long handspikes at a more convenient height than that of the sides of the present traversing platforms.

It would also be an improvement were the traversing curb increased in width, and the handspikes applied, not to the wheel itself, but to a projection, one on each side, from the leg of the platform.

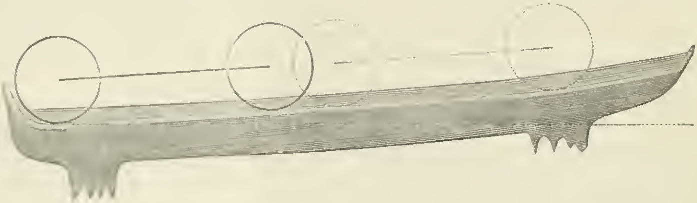
Another cause of difficulty in traversing is consequent on the form of the wheels, which are not sufficiently adapted to the curve in which they move. The two accompanying sketches show the traversing platform as now constructed, and a similar side of one as proposed to be modified.

Present form of traversing platform, showing the position of the front truck when run up, the space occupied by the carriage, and the position of the rear truck after recoil.



In the latter the rise is at first gradual, $\frac{1}{2}$ inch to a foot, and then increases so that the ultimate rise is the same as if it had proceeded from the beginning at 1 inch per foot, the advantage of which is that the first shock is not so great. At the point where the shock is first received the thickness is augmented, and instead of the front stop being so constructed as to receive the full shock of the front truck, as in the first figure, it is gradually curved, and will therefore quietly extinguish the velocity acquired.

Proposed form of traversing platform, showing the position of the carriage before and after recoil.



I may further observe, that the objection of excessive length (16′ 6″) applies to Lieut.-Colonel Emmett's dwarf traversing platforms, particularly as the gun carriage itself is not to be supported by trucks, but by chocks: as, however, it does not appear to have been intended for traversing in an extensive curve, the evil will not often be practically felt. I shall conclude these remarks by observing, that whoever has noticed attentively the present mode of running up a gun on a common platform, must have been struck by the clumsiness of the process; and I would therefore suggest that the principle of traversing should (as in a rough way it actually is in the Madras platforms) be extended to all guns.

This would require an iron frame corresponding to the top of the traversing platform, supported by a pivot either in front or in the centre, and by small well-constructed rollers in the curve of traverse. This frame should be received in a depression of the ground so excavated that the summit of the frame should be flush with the surface; and between each pair of platforms or guns the ground should be raised 2 or 3 feet, or a low broad wall built, which would act as a dwarf traverse, and augment the chances of security of the platform, whilst the shot might still be piled upon it.

This is in part similar to the plan adopted by Colonel Harding, R.E., at Gibraltar, though in that case the platform is raised on a solid wall, and becomes a traverse to the space between the guns.

MORTAR PLATFORMS.

In platforms for this class of ordnance it might be supposed that there is little room for uncertainty, as the recoil both from the vertical direction of the fire, and from the nature of the friction (being that of sliding), is usually considered very small. General Pasley has, however, observed that "the recoil of mortars is rather capricious; it is small when the mortar bed moves upon a rough dry surface, and great on a smooth wet surface;" and when it is remembered that the proportion in weight of the loaded shell is to that of the mortar only as 1 to 68, this amount of recoil, under such circumstances, will not be a matter of surprise.

On referring to received authorities for the proper dimensions of such platforms, some uncertainty appears even as regards wooden platforms, and no data can be found by which the rule for one material can be so modified as to suit the other. Spearman (ed. 1828) gives a number and dimensions of planks which would imply a length of 10′ 10″ and breadth of 13′ 6″, though his sleepers are estimated at 9′ 3″ only; and the dimensions adopted by General Pasley are—length 7′ 6″, breadth 6′ 6″, which are amply sufficient for a wooden platform.

At this station the stone mortar platforms had been estimated at 8 feet square, or nearly in conformity with General Pasley's rule for those constructed of wood; but a sense of the insufficiency of their dimensions had led to some alteration of dimension, and the Commanding Royal Engineer, Lieut.-Colonel Thomson, had laid down as a rule for the station, that stone platforms for 13-inch mortars should be . . . . 10 feet square.

Ditto for 10-inch ditto 9 ,,
Ditto for 8-inch ditto 8 ,,

Still it was desirable to test the question by a direct reference to experiment, and here again Lieut.-Colonel H. W. Gordon, Royal Artillery, came to the assistance of the Department, and obtained the authority of His Excellency Lord Seaton to fire a number of French shells from a 13-inch mortar placed on a stone platform at Cape Sidero; the platform being formed of cubical blocks (2 feet each side) of white limestone, resting horizontally on a bed of concrete 4 feet thick. The result of this first experiment is as follows:

Recoil.		Time of flight.	No. of rounds.	Total weight of six 12·5-inch shells.			Remarks.
Feet.	Inches.	Seconds.		Metal, lbs.	Sand, lbs.	Total weight, lbs.	
6	1	22½	1	168	17	185	
5	1	22	2	150	24	174	Platform sanded.
4	9	22	3	168	16	184	
5	2	22½	4	158	23	181	
4	11½	22	5	159	23	182	
4	8	22½	6	159	28	187	
Charge, 9 lbs. of powder.				Total		1093	
				Average lbs. . .		182	

giving a maximum recoil on the unsanded platform of 6′ 1″, and an average recoil on the sanded platform of 4′ 11″, the mortar recoiling, even when placed flush with the front of the platform before firing, about 15 inches beyond the rear.

A result so different from that of practice on wooden platforms, in which the average recoil is stated by General Pasley to be, under favourable circumstances, only 14 inches, naturally induced the Commanding Officers both of the Artillery and Engineers, to wish to have the experiments repeated on a wooden platform, and for this purpose directions were given that some pieces of old fir scantling should be formed into a platform for the purpose; and the manner in which this was effected by Mr. Mennie, the intelligent Clerk of the Works at this station, affords a hint for a very simple and effective construction of platform, of which I shall presently avail myself. The temporary platform was placed over the stone platform before used, and secured from any retrograde movement by pegs driven into the ground. The result of this practice is exhibited in the following return:

Recoil.		Time of flight.	No. of rounds.	Weight of six 12·5-inch shells.			Remarks.
Feet.	Inches.	Seconds.		Metal, lbs.	Sand, lbs.	Total weight.	
1	6	21	1	159	22	181	
1	9¾	22	2	166	23	189	
1	8¼	23	3	154	22	176	
1	8	24	4	141	27	168	
1	6¼	20	5	142	24	166	
1	9¼	23	6	157	24	181	
Charge, 9 lbs. of powder.				Total		1061	
				Average lbs. . .		176⅝	

The average recoil was therefore 1′ 8″ nearly, or 3′ 3″ less than on the stone platform.

This great excess of retardation in the wooden platform is partly due to the greater amount of friction between iron and wood than between iron and stone, as is shown by the following constants of friction extracted from Poncelet's 'Mécanique Industrielle,' viz.:

At the moment of entering into motion after continued rest,

Iron upon wood (surfaces dry)	0·60
Iron upon hard limestone	0·42

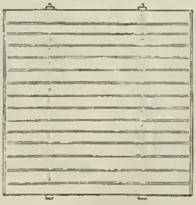
After motion has commenced,

Iron upon wood (surfaces dry)	0·42
Iron upon hard limestone	0·24

and partly to the yielding of the wood under the shock of firing, which, if the wood were non-elastic, must swallow up in its change of form a portion of working force; and if elastic, must at least produce the effect of an uneven surface, and cause the mortar to rise up an inclined plane. It is unnecessary to pursue the subject further theoretically, as the practical result confirms the propriety of Lieut.-Colonel Thomson's caution in increasing the dimensions of the platforms, and demonstrates the advantage of wooden platforms generally.

Reverting now to the subject of the temporary platform already alluded to, it consisted, as put together by Mr. Mennie, of fifteen pieces of fir scantling, 8 feet long, being timber obtained from demolished buildings.

They were put close to each other, and tied together by two long iron rods or bolts, passing through the whole, and secured at the ends by nuts: it was therefore of the annexed form, two ribands, which, however, might be omitted, having been attached at the sides.



Nothing can be more simple than this construction, and apparently nothing more efficient, as the bed of the mortar in the practice here recorded made no impression whatever on the platform, although it suffered, as is always the case in platforms of fir, by the action of the handspikes in running up.

In the adaptation of this form of platform, which it is now my intention to propose for general adoption, the scantling will be 8″ by 8″, the length of the pieces or breadth of the platform 6 feet, the number of them, eleven, being equivalent to a length of 7′ 4″; whilst in General Pasley's platform the length is 7′ 6″, and the breadth 6′ 6″, that breadth being diminished by ribands to 5′ 10″ in the clear. This platform will, in permanent works, be simply laid down on a bed of concrete, 3 feet thick, being kept from recoil by abutting against a small stone platform, of which more hereafter. In the field, the ground must be levelled and rammed, and pickets driven in at the rear of the platform. Of the simplicity of this plan, which requires only one description and size of wood, there can be no doubt, and it can only require modification in very soft ground, when it would be quite sufficient to place under it two sleepers, of a similar scantling, one under each connecting rod.

Let, now, the weight be inquired into and compared with the ordinary field platforms.

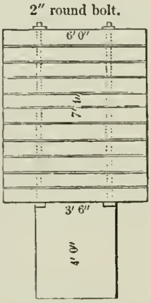
If made of oak—weight in wood	1313·75
,, in iron	53·75
	1367·50
If made of fir—weight in wood	915·64
,, in iron	53·75
	969·39
General Pasley's platform, fir sleepers and oak planks,	1118 ℔s.
Ditto, made entirely of fir	1057 ℔s.

So that a platform of this construction, if made of oak, exceeds in weight the first of General Pasley's, or that having oak planks, by 249 ℔s.; and if made of fir, falls short in weight of General Pasley's platform, made of the same material, by about 188 ℔s.; and if provided with two sleepers, 7 feet long, and of the same material, to meet the case of soft ground, the total weight of the platform would be 1163·6, or only about 6½ ℔s. heavier than General Pasley's platform, whilst in solidity and facility of manipulation it would greatly surpass it.

This description of platform I propose to call solid platforms; and it appears to me that the simplicity of this construction, and the ease with which they can at any time be put together, renders it unnecessary that they should be exposed to the destructive effects of the weather. In fortresses, therefore, the foundations, whether of concrete or of sand, gravel or hard earth, should be made ready to receive at any time the platform; and in rear of and contiguous to this prepared base should be a small platform of stone, the surface of which ought to be on the level at which the surface of the solid platform when laid will stand. On this small platform the mortar bed will be placed when it is intended to remove the solid platform and put it into store; and on the other hand, when the solid platform has been again laid down, preparatory to service, its end will abut against the small platform, and the mortar may be readily slipped from the latter upon it.

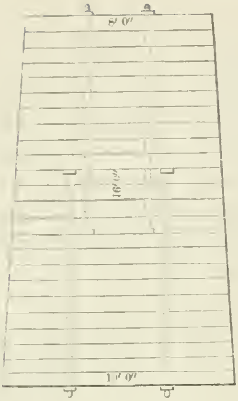
I propose to call the small platform a resting platform, and the whole arrangement, as suited to a 13-inch mortar, will be at once understood by the annexed diagram.

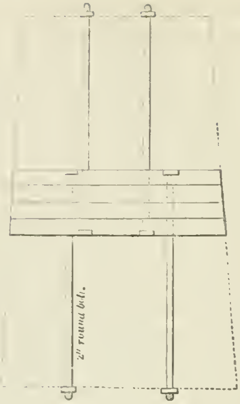
In respect to mortars of a lesser calibre, the size of the prepared platform is so reasonable that it does not appear necessary to diminish it for smaller mortars; and the great advantages are therefore attained, that the size of mortar which at any time it may be found desirable to use, can be adopted without an alteration of the platform, and that either mortar or platform becoming unserviceable, can be at once replaced by another.

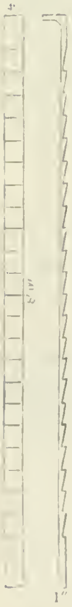


In a similar manner, by preparing additional beds and resting platforms, the platforms intended for one front or division of a fortress may be laid down at any other, and the mortar batteries augmented in force according to circumstances.

The principle of solid platforms is equally applicable to gun platforms, but, on account of their greater length, the bolts or tie-rods must be in two sets, and the platform will be put together, beginning with the centre and proceeding to the two ends, as shown in the following diagrams:

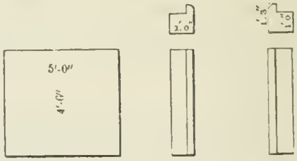






By this arrangement each set of rods passes through fourteen pieces, or 9′ 4″ in length, and at any time that portion of the platform, by leaving out the other pair of rods, may be used by itself, to meet any unexpected contingency, or may replace a similar portion of any other platform rendered unserviceable.

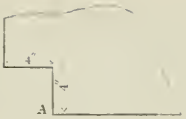
Should it be thought desirable to keep all but a limited number of the platforms in store—either resting platforms, 4′ 6″ by 5 feet, must be placed, as in the case of mortars, behind the platforms, to receive the gun, or resting curbs, one for each line of trucks.

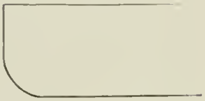


The injury done to the platforms by the action of the handspikes in running up has been already noticed.

This might be obviated in mortar platforms by the use of two racked iron plates, prevented from slipping backwards by stops abutting against the front of the platform. One of these would be placed close to the mortar bed on each side, and the handspikes would act on the racks, so as to keep the plate steady, and bearing on the stop.

To lessen the friction in running up, the form of the mortar bed should also be altered. At present it is thus shaped, so that on each lift of the handspike it bears on a sharp edge at A, and presses into the platform: the base should be rounded thus.





On this particular subject I have only further to notice that the concrete, sand, or gravel bed, prepared for the platform, should be covered with a layer of either cement or tarras, to preserve a smooth, even, and regular surface, always ready for the reception of the platform.

I shall close these notes by a few remarks on the slopes of platforms, and on the advantage of applying the traversing principle in all cases.

1st. As regards the slope of mortar platforms, though it has been usual in our service to lay them horizontal, the rule laid down by Vauban (Att. et Def. tom. i. page 80, ed. 1737,) was to give them a slope of 1 inch in 3 feet, and this rule was subsequently adopted by General Pasley in his improved mortar platform.

The reason assigned by General Pasley is that the shock of the mortar tends to beat down the portion of the platform receiving it, and that in consequence such portion should be more raised than the rest; but this appears unsatisfactory, as the result would be an unequal or convex surface.

To guard against such unequal sinking, the thickness of the concrete or other foundation might be increased at the point of greatest shock; and as regards the object of Vauban in recommending a slope, I am inclined to think it had reference only to the recoil.

From the mode of laying mortars in line, I am inclined to think any material slope of the platform injurious, as it must be evident that if the mortar be traversed much out of the line of the bisecting vertical plane, it will be in a plane inclined to the vertical plane, whilst the pointers used for direction are vertical, and consequently that precision of firing may be materially affected. I therefore think that mortar platforms should be laid horizontal.

The same cause affects, though in a minor degree, the firing of guns, and is an additional reason for adopting a sunk traversing platform, in which the gun is always retained in a vertical plane.

2nd. My preceding remark renders it only necessary to repeat, in respect to the principle of traversing, that it might be simply and easily attained by adopting an iron frame, similar in structure to the top of the present iron traversing platform, the trucks of which should be so attached to the frame as to raise the rear portion of the slide or rail 1 foot from the surface, whilst the pivot in front would be sunk, in order to place the front of the slide nearly level with the surface, the platform being 13 feet long, and the slide or rail portion having a slope of 1 inch in 1 foot. I do not think it necessary to enter into further detail on this subject, and I shall conclude these Notes, which I submit to the consideration of my Brother Officers both of the Artillery and Engineers, with this observation,—that in order to restore the balance in favour of the defence, if such can be done, the effects of vertical fire, and in the case of sea attacks, of musketry fire, must be guarded against by casemating the batteries, or at least the embrasures, and by securing the guns, if not casemated, from the effects of ricochet fire, by the introduction of traverse walls between the guns, in addition to the ordinary traverses. Every thing also which facilitates firing and the general manipulation of the gun, by rendering the running up and traversing more ready and convenient, contributes also to this great result. I may finally remark, that I should have hesitated to submit these Notes, did I not believe that I have the concurrence in their propriety, of my two experienced friends, Lieut.-Colonel Thomson, Commanding Royal Engineer, and Lieut.-Colonel H. W. Gordon, Commanding Royal Artillery, in these Islands.

The subject of traverses I hope to take up generally in another Paper, as it does not appear to me that their position at present is determined upon sufficiently fixed principles.

J. E. Portlock,
Captain, Royal Engineers.

Corfu, Oct. 4, 1844.

III.—*Description of Siege Gun and Mortar Platforms.*
By Lieut.-Col. ALDERSON, *R.E.*

SIEGE GUN AND MORTAR PLATFORMS.

1st. THE object of the construction of siege gun and mortar platforms is to place the artillery in battery on hard level surfaces capable of retaining their position, and of enabling the artillerymen to make correct practice with fewer men, from the facility afforded for running the gun or mortar up after each discharge.

2nd. As these works have generally to be laid under fire, and frequently during the night, the more simple their construction and the more uniform their parts, the better.

GUN PLATFORM.

3rd. The gun platform now to be described, and which has been satisfactorily proved by the Royal Artillery practice at Woolwich, has therefore been made to consist of baulks of uniform length and scantling, which serve both for sleepers and planking.

Each baulk is a piece of timber 9 feet long, 3½ inches thick, and 5 inches wide, weighing about 37 ℔s., sufficiently light to be carried to the spot by one man, besides his arms and ammunition, and, being universal, it will fit into any part of the platform.

4th. This is the minimum size, but if made on the spot, or in the field, the principle may be equally adapted to any other increased dimensions; and thus render available such timber as may be procured at the time, with the greatest economy of material and labour. If constructed of the minimum dimensions above stated, a gun platform 15′ × 9′ will consist of

	cwt.	qrs.	lbs.
46 baulks, with 47 trenails 10″ long and ¾″ diameter, each of which makes 4 dowels 2½″ long; 1 oak trenail being added for the rear centre pin of platform	15	0	22
9 round iron pins 11″ long, including the eye	0	0	18
10 iron shoes and 20 inch screws	0	1	2
Total weight	15	2	14

Plate IV When the platform is required to be 18 feet in length, the sleeper is formed as shown in fig. 6.

12 additional baulks and trenails,
10 do. iron shoes,
20 do. iron screws,

will then be required, adding 1 cwt. 0 qr. 26 lbs. to the weight of the platform.

Figs. 1 and 2 represent a baulk of the above-named dimensions, with eight holes bored 1¼ inch deep and ¾ inch diameter, at the distances specified, four on each side of two opposite sides, both sides being alike when taken from opposite ends. Oak dowels 2½ inches long and ¾ inch diameter (four of which are obtained from each trenail) are then introduced half their length into the holes on one side of each baulk.

Figs. 1 and 2: *a*, *b*, *c*, *d*, represent the dowels, and *e*, *f*, *g*, *h*, the holes.

Fig. 9 represents three baulks (with their pins complete) of 10 feet each in length, which must be used when the platforms are required to be 10 feet *in width*. Of these baulks, *a* and *b*, or *a* and *c*, show how two are put together to form a sleeper when the platform is to be 10′×15′. The three together, *a*, *b*, and *c*, show the mode of forming the sleeper for a platform 10′×20′, if required; but the flooring need not necessarily extend to the ends of the sleepers. The platforms, whatever may be their dimensions, are put together in precisely the same manner.

The 10-feet baulk weighs about 41 lbs.

5th. Into the end of the dowel which enters the baulk, a fox wedge (fig. 3) is introduced, to prevent the dowel dropping out. The dowel is then 1¼ inch within the baulk, and projects the same beyond it, and this projection fits into the holes of the next baulk.

6th. In order to lay a gun platform, take any ten of the baulks and dowel them together two and two, as shown in fig. 4; each two baulks will then form one sleeper 15 feet in length.

7th. It is to obtain this length that the holes are bored at the distances specified. Two iron shoes 2 inches broad and ½ inch thick are then fitted on and fixed with a small screw, as shown in figs. 4 and 5, to keep the sleepers steady.

8th. Fig. 6 shows how the sleepers may be made 18 feet with the same baulks, should it be requisite, from the nature of the ground, to prevent the trail of the gun recoiling off the platform, which a 32-pounder invariably does, with service charge, when the platform is 15 feet in length, laid with the usual fall to the front of ½ an inch per foot.

9th. Each platform requires five sleepers, which must be laid in the space of 9 feet, the width of the intended platform as shown in fig. 4. Before laying the platform, holes, ¾ inch diameter, must be bored 2½ inches from one end of each sleeper, and that end is to be placed at the *front* of the platform.

10th. The platform is now laid in the usual manner by excavating trenches to receive the sleepers, and, after levelling them with the field level, securing them in their places by filling in the trench on both sides of the sleeper, and ramming it well, taking great care not to injure the sleeper.

11th. Next take any one of the baulks and lay it transversely on the ends of the five sleepers, over the holes thus bored, and bore five similar holes through the baulk immediately over them, as shown in fig. 7.

12th. Place five iron pins through these holes of the transverse baulk and through the corresponding holes in the ends of the sleepers, fig. 7; the position of the sleepers in front will then be secured.

13th. In the rear a baulk must only be placed *over* the ends of the sleepers as a guide, but without boring either, as the exact place for the holes cannot be determined until the last baulk of the platform is laid, and as it is not necessary that all the baulks should be one width.

14th. When the last baulk of the platform is laid, bore through it and the ends of the sleepers as in front; insert the pins, and the platform is fit for use.

15th. The centre *rear* pin is to be an oak trenail; it will then be flush with the platform, and let the trail of the gun recoil without meeting with any impediment.

16th. The platform thus laid is a clear uninterrupted surface of 9′ × 15′, or 9′ × 18′, as the case may be, with the exception of the heads of the pins front and rear, a portion of which is shown in fig. 4.

17th. It will be evident that in the construction of this kind of platform the holes in each baulk must be bored at *precisely* corresponding distances, and this it is proposed to effect by the construction of a dowel box, which may be easily done at the engineer park in the following manner.

18th. If the carpenter's bench be long enough, no bottom piece will be required; if not, a bottom piece or plank (*kkk*), and upon it an end piece placed transversely (*l*), a front piece (*mm*), and a rear piece or cleat (*nn*), with four wedges (*oooo*), laid longitudinally. The front piece must be bored at the required height and distances 1, 2, 3, 4.

19th. The baulks being then made of the required thickness and squared, are placed one at a time into the dowel box, and pushed home to *l*; the baulk (P) is then wedged tight up to the inner side of the front piece, and is bored with a ¾ centre bit through the holes before mentioned. Prior to its being taken out of the dowel box, after one side is bored, it must be made exactly of the proper length by sawing the end (*q*) to the gauge shown by the saw kerf on the dowel box; the baulk is then taken out, turned over and end for end, refixed in the dowel box, and again bored: in this way every baulk must be similar in every respect.

20th. Iron pins and shoes have been introduced in the construction of these platforms to enable them to be easier *relaid* during the siege; but for all the purposes of strength, the wooden pins or trenails will answer; and the shoes, excepting in bad ground, may be dispensed with, or made of wood, if required.

21st. In taking to pieces a platform *thus* laid, the wooden pins or trenails must be driven or bored out and fresh provided, if the platform is required to be *relaid;* the iron pins therefore are to be preferred.

An additional supply both of iron pins and oak trenails should accompany every siege equipment, as the small-sized scantling required for the platforms will almost always be found on the spot.

MORTAR PLATFORMS.

Plate V. Siege mortar platforms for 8-inch and 10-inch mortars may also be constructed of the same baulks and pins used in the gun platforms.

An 8 or 10-inch mortar platform of this kind will consist of

	cwt.	qrs.	lbs.
24 baulks, (18 as deck, 6 as sleepers,) with 24 trenails 10 inches long and ¾ inch diameter	7	3	30
12 iron pins	0	0	24
Total weight	8	0	26

This will make a platform 9 feet × 7 feet 6 inches (fig. 1); the flooring can be diminished or increased to 9 feet square, as may be deemed necessary.

The ends of the sleepers will necessarily project in a platform of the above dimensions; should they be in the way, they can be cut off where the deck ceases: this will, however, prevent their sleepers from being used in any other description of platform.

The sleepers can also, in case of any bad ground, be doubled, by merely dowelling two together, and putting on two of the iron shoes used in the gun platforms, as shown in fig. 2.

The platform fig. 1, has, like the gun platforms, been satisfactorily proved by the Royal Artillery in the marshes at Woolwich.

13-inch mortars are scarcely considered siege artillery, from the difficulty of obtaining transport for them.[1]

Still, as this difficulty is frequently overcome, either from the facility of obtaining water carriage, good roads, or the place to be attacked being on the seaboard, it is necessary that platforms should be provided for them.

The platform for 8 and 10-inch mortars, even with the addition of double sleepers, formed by two baulks dowelled together as in fig. 2, and double pinned, has been found insufficient to bear the great weight and shock of a 13-inch mortar, in the soft ground of the marshes at Woolwich. Should it therefore become necessary to lay a 13-inch mortar platform with the universal baulk before referred to, the following plan is recommended.

Lay three double sleepers, similar to fig. 2, transversely, or parallel to the interior slope of the battery, as front, centre, and rear of the platform (figs. 2, 3, 4); on these lay two floors transversely to each other, the lower floor corresponding with the sleepers on the 8 and 10-inch mortar platform. Pin the whole down as shown in fig. 3, which represents a front or rear elevation of the platform. Fig. 4 shows a plan of a portion of this platform.[2]

Or, a separate platform may be constructed of baulks on the same principle, by increasing their dimensions to $5\frac{1}{2}$ or 6 inches square, according to the size of the timber to be obtained, and laid in the same manner as the 8 and 10-inch mortar platform.

---

[1] In the twelve siege operations during the late Peninsular War, no instance occurs of a 13-inch mortar being used, and even 10-inch mortars only at the sieges of Ciudad Rodrigo, St. Sebastian, and the blockade of Pampeluna. In the preparations for the siege of Bayonne, four 13-inch mortars were provided, but the land carriage from Passages was short, and time was given to the Engineer Department to make ample preparations for the approaching siege.

[2] Since writing the above, this mode of laying a platform for a 13-inch mortar has been tried in the marshes at Woolwich, and found to answer very well.

This platform, as well as the 8 and 10-inch one, may also be strengthened, if necessary, by having the sleepers *doubled*, on the same plan as shown in fig. 2.

Either of these modes is considered preferable to increasing the size of the gun platform baulk, which being found strong enough for general siege operations, has the great advantages of being universal, and light enough to be carried to the trenches by an armed soldier.

It is proposed in a future Paper to show that the universal platform baulk may be made applicable to the construction of lean-to expense magazines and mining frames.

R. C. Alderson,
Lieut.-Colonel, Royal Engineers.

Note.—In the beginning of 1844, siege platforms on this principle were submitted by me to the Master-General through the Inspector-General of Fortifications, and were ordered for trial and Report by the Select Committee at Woolwich.

They were of four different dimensions:

	ft.	in.		ft.	in.	
No. 1	9	0	×	14	2	each with four sleepers.
2	9	0	×	15	0	
3	9	6	×	15	0	
4	10	0	×	15	0	

One of each kind was constructed by the Engineer Department at Woolwich, and laid in the marshes by the Royal Sappers and Miners under the orders of Colonel Sir George Hoste, C. B., Commanding Royal Engineer, in May.

The Commandant, General Lord Bloomfield, G. C. B., ordered that a 24-pounder on siege carriages should be mounted on each platform, and 100 rounds, with service charge of 8 lbs. of powder at $\frac{5}{8}$ elevation, should be fired for each gun, and the result reported by the Select Committee.

On the 23rd August, the firing commenced, and continued at intervals till the 26th November, without the platforms requiring to be relaid.

On being taken up after the practice was completed, the platforms were reported as efficient as on the day on which they were laid down.

In the course of the practice, however, it was ascertained that the rear pin-holes in the ends of the sleepers showed a tendency to become elongated from the great strain on the rear pins.

This was remedied by driving a stake or large picket immediately in rear of the end of each sleeper, until the top of the picket was level with the upper surface of the deck of the platform.

These pickets were also found of service to the rear deck pieces, on which there is the greatest wear and tear, owing to the trail of the gun recoiling off the platform on each discharge.

Should this baulk require replacing, it may be done in a few minutes by making it change places with the one next to it, or with any other piece of the platform.

The baulk which supplies its place must be bored to receive the pins.

In relaying these platforms it will be desirable to turn the rear baulk of each *sleeper*, end for end, should the pin-hole in it be elongated, boring a fresh hole.

If different kinds of wood are used in the construction of these platforms, the hardest should be selected for the sleepers and for the outside or front and rear deck pieces, through which the pins pass.

During the practice it was suggested by the Select Committee that a 5th sleeper would be an improvement, as there would then be one under each of the wheels as well as under the trail of the gun. This was accordingly carried into effect in No. 4, and, though all the platforms behaved equally well, it was considered so judicious an alteration, in case of very bad ground or very continuous firing, that it was adopted.

As all the platforms were alike in principle, and varied only in the extent of surface, No. 2 was selected, as presenting the minimum width with the maximum length.

Sir John T. Jones, in his History of the Sieges in the Peninsular War, (vol. ii. p. 196, Note on Platforms, 2nd. edit.), states that, " perhaps on further trial 15 feet may be deemed sufficient length and 9 feet sufficient breadth for siege platforms, which would still further reduce the weight."

The principal feature in the construction of these platforms being the adoption of one light universal scantling, it was deemed very desirable, if possible, to make the same baulk answer for mortar as well as gun platforms.

With the concurrence, therefore, of the Select Committee, the mortar platform (fig. 1) was laid of a portion of the baulks of one of the above-named platforms, in the softest part of the marshes at Woolwich, and a 10-inch mortar mounted on it. The result proved satisfactory, (see Report attached, paragraph 4;) by which it appears nine out of seventy-two of the dowel pins were broken: this is not to be wondered at, when it is recollected that the materials of these platforms had been laid, exposed to the weather, from May, 1844, to February, 1845, and that the sleepers had not been tarred or any other precautions used to preserve them, and, above all, that the practice had been at an angle of 75° in bad ground.

A platform also 9 feet square, of a portion of the same platforms, with six double baulks similar to fig. 2, was laid near to the 10-inch platform, and a 13-inch mortar mounted upon it, and fired also at 75° elevation. This platform showed weakness. After four rounds, that part of the deck of the platform on which the bed of the mortar stood, and all behind it, on the mortar being fired, slided 15 inches bodily to the rear, without moving the sleepers, but forcing the pins through their ends; the pins themselves not being, in the slightest degree, bent or injured.

As the platform was stated not to have sunk at all, I proposed that *each* of the two baulks forming the double sleepers should have a pin through it in front and rear, instead of *one* of the baulks only, as hitherto.

The platform was accordingly laid on this principle, that is, with a double set of pins. The result of this trial is given in the accompanying Report, paragraphs 1, 2, and 3; by which it will appear that the platform was wholly unequal to so severe a trial as a 13-inch mortar fired at 75° elevation in soft ground, and that either greater strength must be given to the platform, or the foundation be prepared by first laying fascines, fagots, or hurdles.

These various trials led to the suggestion of the mode of constructing a 13-inch mortar platform, as described at page 29.—See figs. 2, 3, and 4, Plate V.

R. C. A.

(COPY.)

Report on Colonel ALDERSON'S *Platforms for a* 13-*inch and* 10-*inch Mortar.*

1. These platforms were yesterday removed from the marshes. Twenty-five rounds have been fired from each. The following defects were noticed during the process of taking up.

2. In the 13-inch platform, between the fourth and fifth floor piece, an interval of $1\frac{1}{4}''$ in breadth was observed. The surface of the seventeenth floor piece was very much splintered. This was the piece against which the rear of mortar bed abutted; and the weight of the mortar and bed, together with the recoil, which was very great in an almost vertical direction when the elevation was increased to 75°, having caused a perceptible deflection in all the floor pieces upon which the mortar bed rested, the abrasion of the surface of the seventeenth floor piece was thus caused by the resistance it offered to the horizontal recoil of the bed of the mortar.

In the fourth floor piece two dowels were broken, in the sixteenth one dowel broken, and in the seventeenth one dowel broken. The pin-holes in the rear of the sleepers were much enlarged; of course owing to the recoil.

3. A great deal of soil had found its way between the floor pieces and the sleepers, and it seemed that if the platforms were to be much more used, the accumulation of soil would become so great as materially to lessen the hold of the pins.

4. The 10-inch platform was in no way injured, except in the dowels being broken.

The fractures were as follows:

1	in the	2nd	deck pieces.
1	,,	3rd	,,
1	,,	4th	,,
2	,,	6th	,,
1	,,	8th	,,
1	,,	15th	,,
2	,,	16th	,,

Several of the fox wedges were also drawn, although the other end of the dowel remained firm in the floor pieces.

(Signed) C. S. HUTCHINSON,
Lieutenant, Royal Engineers.

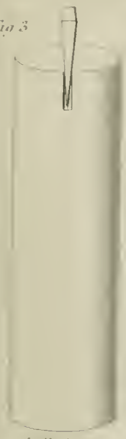
February 27th, 1845.
Woolwich.

SIEGE GUN PLATFORM.

Plate 4

Dowel and Fox Wedge

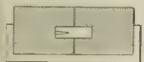
Fig. 3



Full Size

Fig. 5

Section on C D



1 ft to an inch

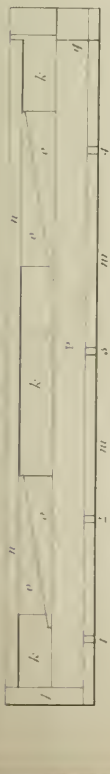


Fig 8 Doyed Box

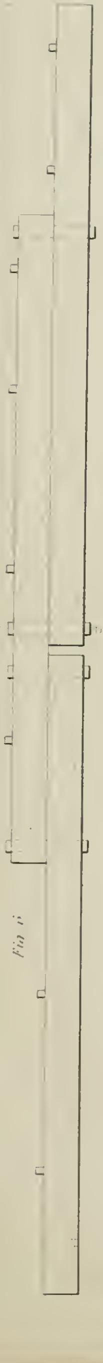
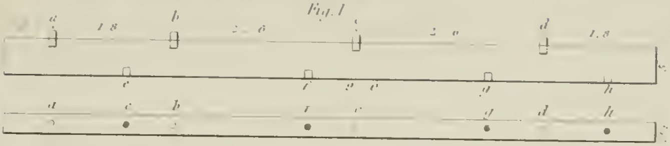
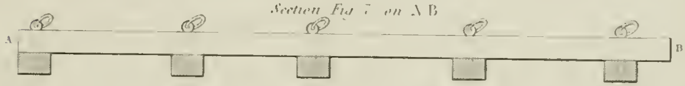


Fig 6

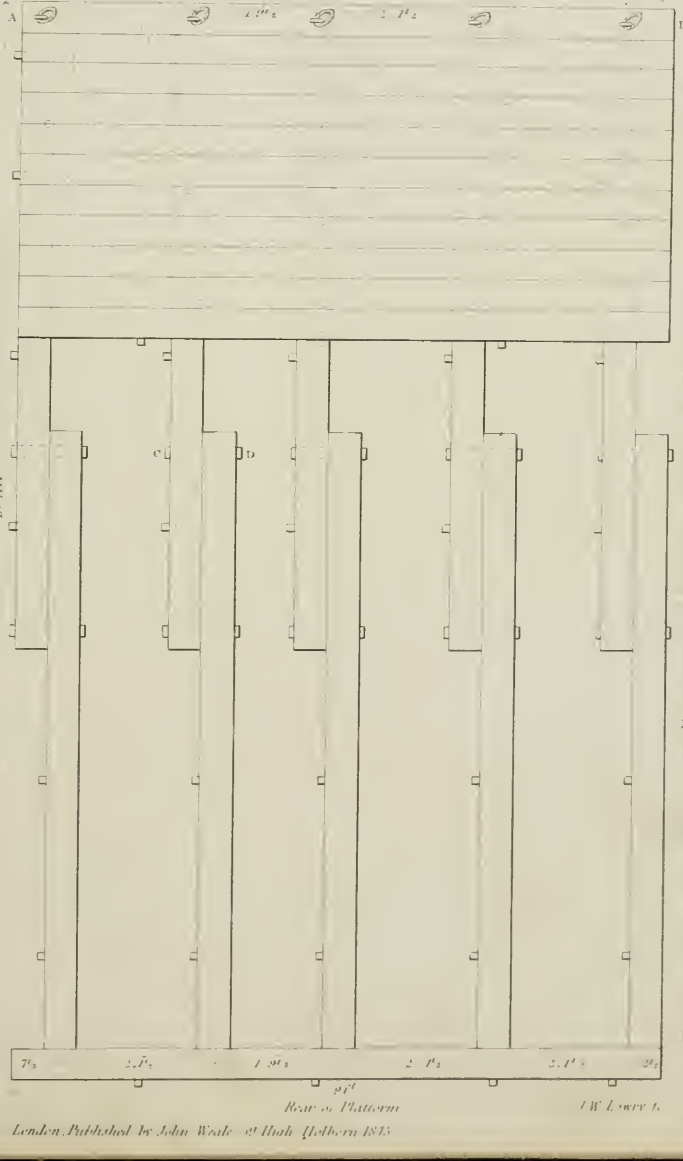
Fig. 1



Section Fig 7 on A B



Front Fig. 4 of Platform



Rear of Platform

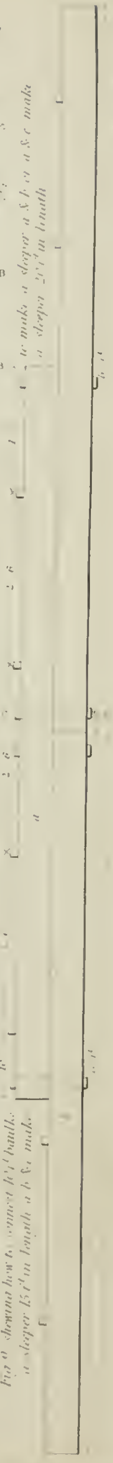


Fig 9 shewing how to connect 10½ ft baulks to make a sleeper a & f or a & c make a sleeper 15 ft in length a b &c make a sleeper 21 ft in length

J W Lowry f.

London, Published by John Weale 59 High Holborn 1845

MORTAR PLATFORMS.

Fig. 1

Plan of a Platform for an 8 or 10 inch Mortar

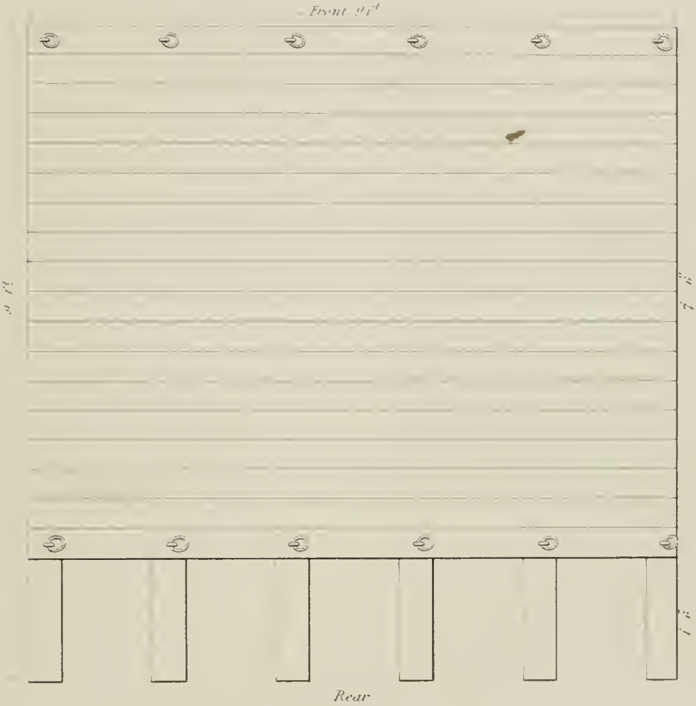


Fig. 2 Plan of double Sleeper for 13 inch Mortar Platform.

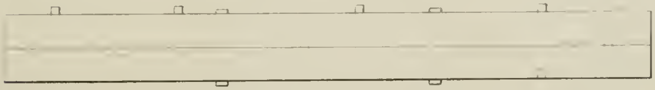


Fig. 3. Front & Rear Elevation of 13 inch Mortar Platform

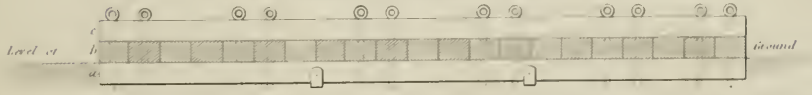
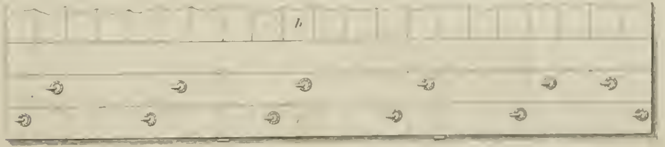


Fig. 4 Plan of a part of a 13 inch Mortar Platform shewing the decks b & c and the mode of [illegible] the [illegible]

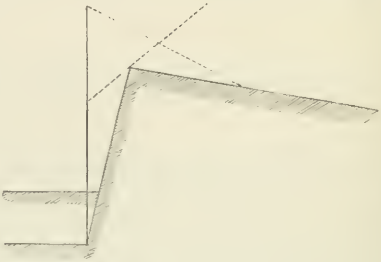


London Published by John Weale 59 High Holborn

IV.—*Notes on the Superior Slopes of Parapets.* *By Captain* Portlock, *R. E., F. R. S., &c.*

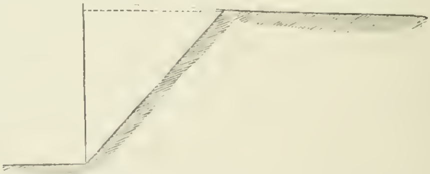
On reading the remarks of Major-General Pasley, in his 'Elementary Fortification,' on the modified forms of banquettes, which have been recommended by various military writers, it has struck me that those writers do not consider sufficiently the relation which ought to exist between every one part of a parapet and every other: and I am at the same time satisfied that Vauban, that great master of military art, who has in modern times found in Arago so eloquent an eulogist, had distinctly before him this relation, combined with a due regard to strength, in the forms and proportions which he adopted. For example, the height of the parapet, 7′ 6″, is evidently the minimum which could be adopted with safety; and for the thickness, 18 feet, Vauban gives as a reason that it is the least which can be used in a parapet exposed to the fire of heavy artillery. The depression of the banquette below the crest of the parapet is the first element to be determined, and it is evidently at a maximum where it equals the mean height of a man's shoulder, say 4′ 8″, but as circumstances may render it advisable to adopt a lesser depression, both the interior and superior slopes of the parapet must be correspondingly modified. Let however 4′ 6″ be adopted in the first instance, and the question be asked, what should be the interior slope. Putting aside the consideration of stability which may be secured in fortresses by sods, by bricks, or by concrete puddling, it is evident that the soldier requires some little space between him and the crest of the parapet for freedom of action; and it will be found that a slope of 1 to 4, which gives 13½″ in 4′ 6″, is a proportion determined practically to be a good one, and that nearly the same space will be taken up by the soldier even if the interior slope be revetted vertically with bricks. The soldier standing behind this parapet will be at 1′ 3″ from the crest; therefore, if the superior slope be 1 in 12, according to Vauban, that slope, continued inwards, will meet the soldier's shoulder at a height of 4′ 6″ + 1¼″, or 4′ 7¼″; and the musket, when brought down to the fire, will be nearly on the same continuous plane with the superior slope.

If now the depression of the banquette be diminished, the superior slope remaining the same, the soldier's shoulder will be raised above the prolongation of the superior slope, and in suddenly bringing his musket to the fire, he will be in danger of striking the parapet, and firing into it; and if the depression be increased, his shoulder will be below the prolongation, and he will be in danger of resting his musket on the crest, and firing into the air, as shown by the accompanying diagram.



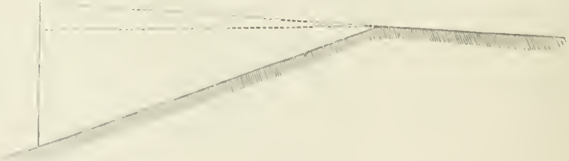
These principles being kept in view, it is easy to test the merits of the several methods proposed.

General Pasley ('Elementary Fortification,' vol. ii. p. 667) recommends an interior slope of 1 to 1, reducing the depression of the banquette to 4 feet.



As the base is here 4 feet, the rise from the crest of the parapet inwards is rather more than 4″, and the prolongation of the superior slope meets the soldier at an elevation of about 4′ 4½″, or 2½″ below the height of his shoulder. This small fischant depression may perhaps be neglected as unimportant; and as the infantry musket is 4′ 10″ long, it will, when brought to the fire, rest by a few inches on the crest.

General Pasley then mentions a mode recommended by Lieut.-Col. W. Reid, an authority, when that Officer's talents and experience are considered, of very great weight. Lieut.-Col. Reid's plan is to make in certain cases the interior slope into one continuous and easy slope, so as to do away with the banquette. The slope to have a base, as compared to the height, of 3 to 1.

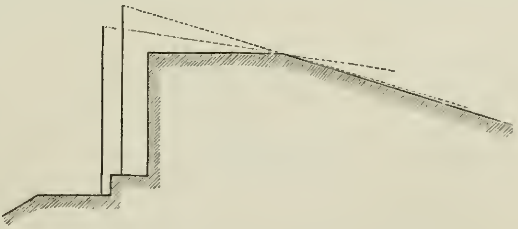


By this arrangement, when the shoulder point of the soldier is in the position corresponding to the superior slope produced, he stands nearly 10½ feet from the crest of the parapet, and his shoulder is elevated 10′ 4″ inches above it, that is, upwards of 9 inches more than it would be with an ordinary banquette, or 2½ inches more than with a banquette depressed only four feet; and as he would necessarily advance somewhat more forward to command more effectually the superior slope, his exposure would be in like manner augmented: but there is another disadvantage in this system, namely, that the crest of the parapet is too distant to afford a rest to the musket, and that the accuracy of the soldier's fire will depend, therefore, solely on his steadiness.

General Pasley has pointed out the inconvenience of thus standing so far from the parapet. If these considerations be carefully weighed, it will, I believe, be admitted that the relative interior slope of parapet and height of banquette adopted by Vauban were established on sound principles, and have not hitherto been improved.

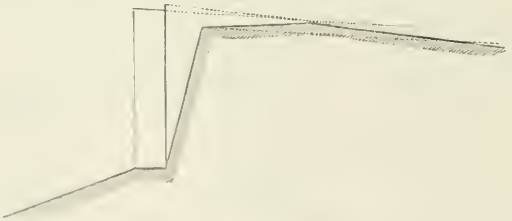
Keeping in view the same principles, they may be applied with modified forms of the slopes to other contingent circumstances; such for example as a very high relief, or a short line of defence, when it becomes difficult to obtain a command by musketry fire of the ditch, counterscarp, or even of the glacis,—defects which in this fortress are strikingly illustrated in the defences of Fort Neuf.

To lessen this evil, it is necessary to keep the base of the interior slope at a minimum, so as to enable the soldier to approach as close as possible to it; to admit of a graduation in the depression of the banquette below the crest of the parapet, in proportion to the slope at which it is desired to fire, which is best done by brick steps; and finally, to make the upper portion of the parapet next the crest horizontal, which horizontal space may be called the crest plane, the more advanced portion being formed into a slope so much greater than the usual superior slope as the necessity of the case may require. To illustrate these propositions, let the annexed diagram be consulted.



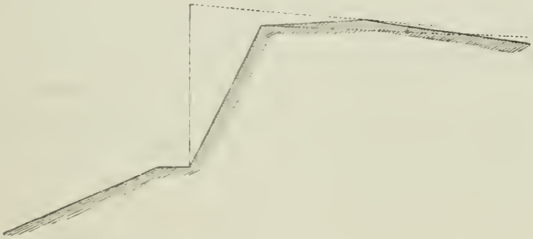
The depression of the first step of the banquette is here considered 3′ 4″; and as the soldier's shoulder would be thereby raised sufficiently above the crest of the parapet to possess a perfect freedom of motion, the interior slope is made perpendicular, and the soldier is supposed to stand about 8 inches from it, the whole breadth of the upper step being 12 inches. With this arrangement, the musket being 4′ 10″ long, the crest plane may be made 4 feet wide, and the superior slope from its termination about 1 in 4, instead of 1 in 12, so as to obtain a fire so much the more plunging as the slope is greater. The actual exposure of the soldier is evidently not greater from fire coming in the direction of the superior slope, than if that slope were continued upwards through the point of intersection with the crest plane, and it is only augmented as increased command is obtained by the assailants' fire. The second step is here considered only 6 inches below the first, and the soldier's body may be considered to approach within 3 inches of the vertical from that step, or by a slight inclination to fall into line with it. The musket will only just reach the edge of the crest plane, and from its diminished elevation will fire in a slope much less plunging (viz. 1 in 7) than in the first case, but more so than in that of the ordinary slope.

The effect as regards the thickness of the parapet of this arrangement is this: that at the crest it is thicker than usual, and that the diminution of its general thickness only takes place at a point where it is 5′ 6″ thick. So great a plunge, however, could only be recommended in such flanking defences as are tolerably covered from the enemy's fire, and are required from either an unusually short curtain or line of defence to possess an unusual plunging command. The next diagram exhibits a simpler mode of construction, in which a plunge of 1 in 7 is obtained.



The interior slope is supposed to stand at 1 to 4. The banquette to be depressed 4 feet below the crest, to be made only 1 foot wide, and with a slope of 1 in 3, by which arrangement a man standing at the top of the slope would fire in the direction of the ordinary superior slope, whilst the direction of the fire could be modified by approaching or receding from the parapet. In this example the parapet is diminished in thickness only up to the point where it is 7 feet thick from without, whilst within it is thicker than before, as shown by the dotted lines.

Supposing now the interior slope of the parapet to be 1 to 2, and there can be seldom any necessity for making the proportion of the base to the height greater, the next diagram will exhibit the form modified according to these proportions.



The breadth of the crest plane is 3 feet, the superior slope from that point 1 in 6, and the external diminution of the thickness of the parapet occurs at a point where it is 6 feet thick, all within that point being of course augmented in thickness.

In parapets of this construction, the sand-bags usually placed on the crest should be arranged along the external edge of the crest plane, as the soldier will thereby derive additional security, and fire through the openings of the sand-bags with ease and certainty; the edge itself in all cases affording a rest for his musket.

A very slight comparison will, I think, render manifest the advantage of this proposed modification. In the usual continuous superior slope, the soldier has no guide to the direction of the fire unless his musket is laid on the slope; and should he stand rather higher than the prolongation of that slope, and suddenly bring his musket to the present, he will be liable either to fire too high or too low into the parapet itself; but in the parapet with a crest plane, if properly adjusted to the interior slope and height of the crest above the banquette, the musket may be depressed until it touches the exterior edge of the crest plane, and be then fired with certainty, as the superior slope from that point has been made to plunge a little below the actual line of fire, whilst a variation in the inclination of the line of fire may be attained by simply retiring a little from the parapet.

In some of the parapets of Fort Neuf, recently restored, the crest plane has been introduced by direction of Lieut.-Colonel Thomson, Commanding Engineer, and its advantages can therefore be now practically studied.

The term 'concrete puddling' has been adopted to signify a very simple expedient for supplying the place of sods in interior revetments. To about twenty or twenty-five parts of clayey gravel is added one of quick-lime, and this is laid down in balls or lumps, and beaten flat along the face of the slope with flat rammers. This sets and hardens like concrete, and there can be little doubt will be found an effective substitute for sods. One large traverse, and the interior slope of the parapet of the face of the right bastion of Scarponi, have been prepared in this way, but of course there has not yet been sufficient time for declaring the experiment successful by trial past, though appearances justify a most favourable anticipation.

V.—*Description of a Loopholed Barrack, intended as a Keep for a Square Fort.*

By Captain FARIS, *R. E.*

THE fortified barrack illustrated in the subjoined Plates has recently been erected at Pembroke Dock, from plans submitted by Colonel Harding, R. E., and I believe that it is the only barrack of the kind in the United Kingdom.

The barrack is calculated to accommodate 400 men, with the due proportion of officers; there is also a residence for barrack-master, canteen, two small powder magazines, barrack store-rooms, &c.

The building being of a square form, with flank towers projecting from the centre of each face, and having a tier of loopholes from each floor above the ground, bearing outwards, is calculated to make a good defence: the angles of the square are cut off for the purpose of giving a direct fire on those parts which are not seen from the rest of the building.

The main entrance to the barrack square is defended by the fire from loopholes on each side of the gateway, and from others above it: on this side of the barrack, the flank tower or caponnière is much larger than the others, and having side galleries on the ground-floor, and loopholes in that and also in the story above, a good flank defence is obtained: there are also openings at each of the angles of the square, which are protected by palisade fences having gateways in them.

It is to be observed that the buildings which in the arrangement of barrack accommodation are generally detached from the main building, such as cells, coal-stores, privies, &c., are here in casemates: by this method the whole of the ground on every side of the barrack is open to the fire from two tiers of loopholes.

Within the barrack square a well has been sunk which will afford an ample supply of water; six tanks have also been constructed to receive the rain-water from the roof: these tanks will contain 89,000 gallons of water; two of them are fitted with sluice cocks, having pipes leading to the soldiers' privies, for the purpose of scouring the latter.

The walls of the barrack are of limestone rubble masonry, the quoins, plinth, and string courses are tool-dressed, the external walls are 3 feet in thickness, the flank towers 2 feet, and the inner walls 2 feet; the partitions are of brick, 14 inches in basement story and 9 inches above; and as a security against damp, so frequent in limestone buildings, the external and inner walls are lined with brick, half-brick thick, bonded to the rubble-work every fourth course, one brick thick: the floors are carried on cast iron girders.

Plate VI. is a general plan of the basement story and casemated out-buildings, showing also the situations of the rain-water tanks, well, and drains: the arrangement of the latter is such that the whole of the surface water from the barrack square, area, and waste from the tanks, is conveyed to two large cesspools, and from thence through the soldiers' privies to the main sewer: this will materially assist to cleanse these privies, and as the cesspools in every part of the building are trapped, no effluvia can possibly escape from the drains. There is also a drain on the outside of the officers' range, passing under the three water-closets, and through the women's privies: this drain receives the water from one-half the roof of the officers' building and from the surface in rear of it; it passes under the floor of the wash-house to a cesspool which also receives the drain from the solitary cells, and thence to the main sewer.

There are four solitary cells, the arrangement and ventilation of which has been adapted, as nearly as the situation will admit, to the directions laid down in the Report on Prison Discipline.

The two powder magazines are calculated to contain 104 barrels each; they are arched over, and being below the level of the ground outside the barrack, have been constructed with a dry area wall on three sides: the entrance, which is under the staircase landing of the basement story, is secured by double doors.

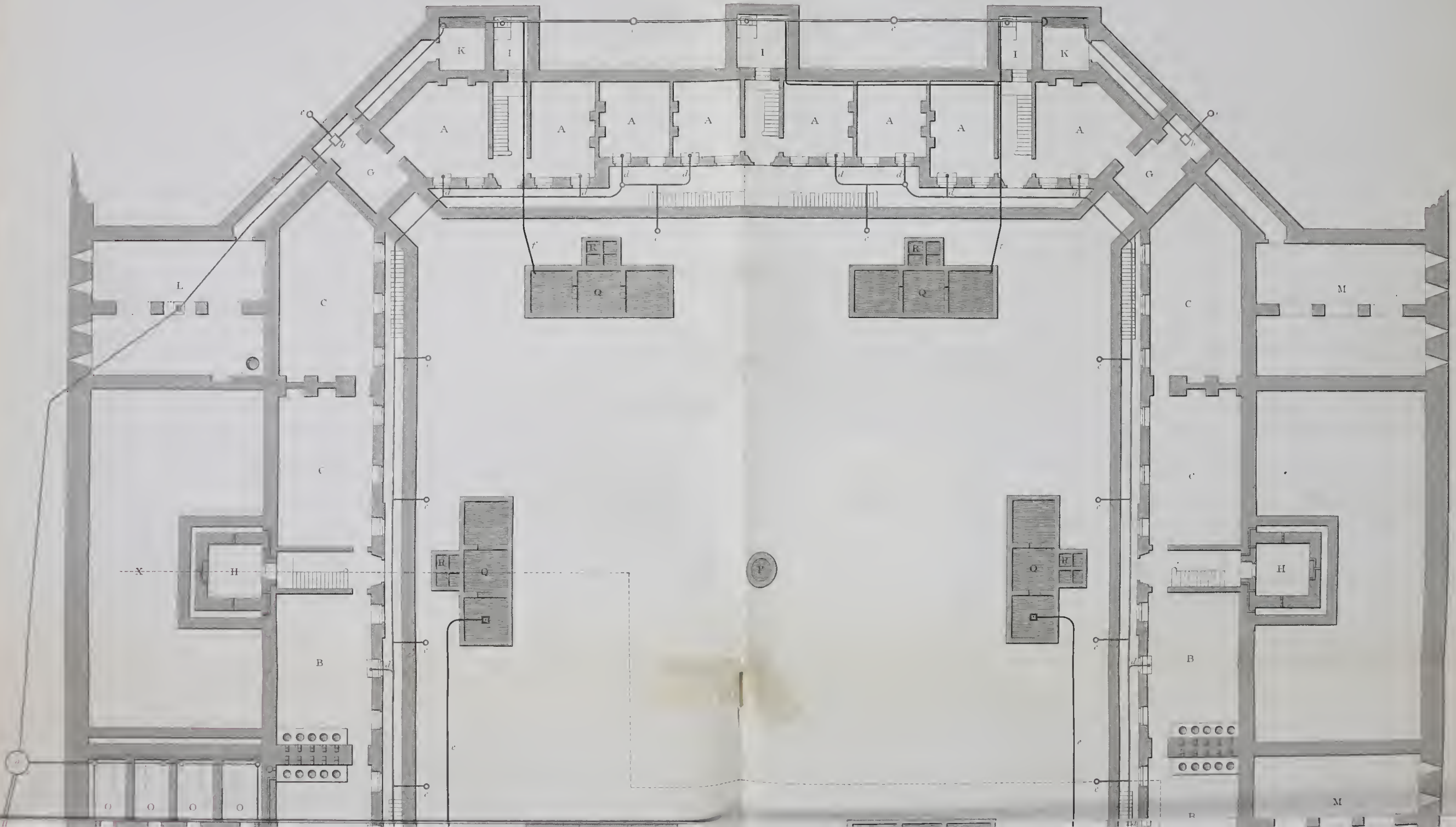
In Plates VII. and VIII. the appropriation of the several rooms on the ground and first-floor is shown, the positions of the rain-water pipes which convey the water from the roof to the filterers, as also the surface drains and channels.

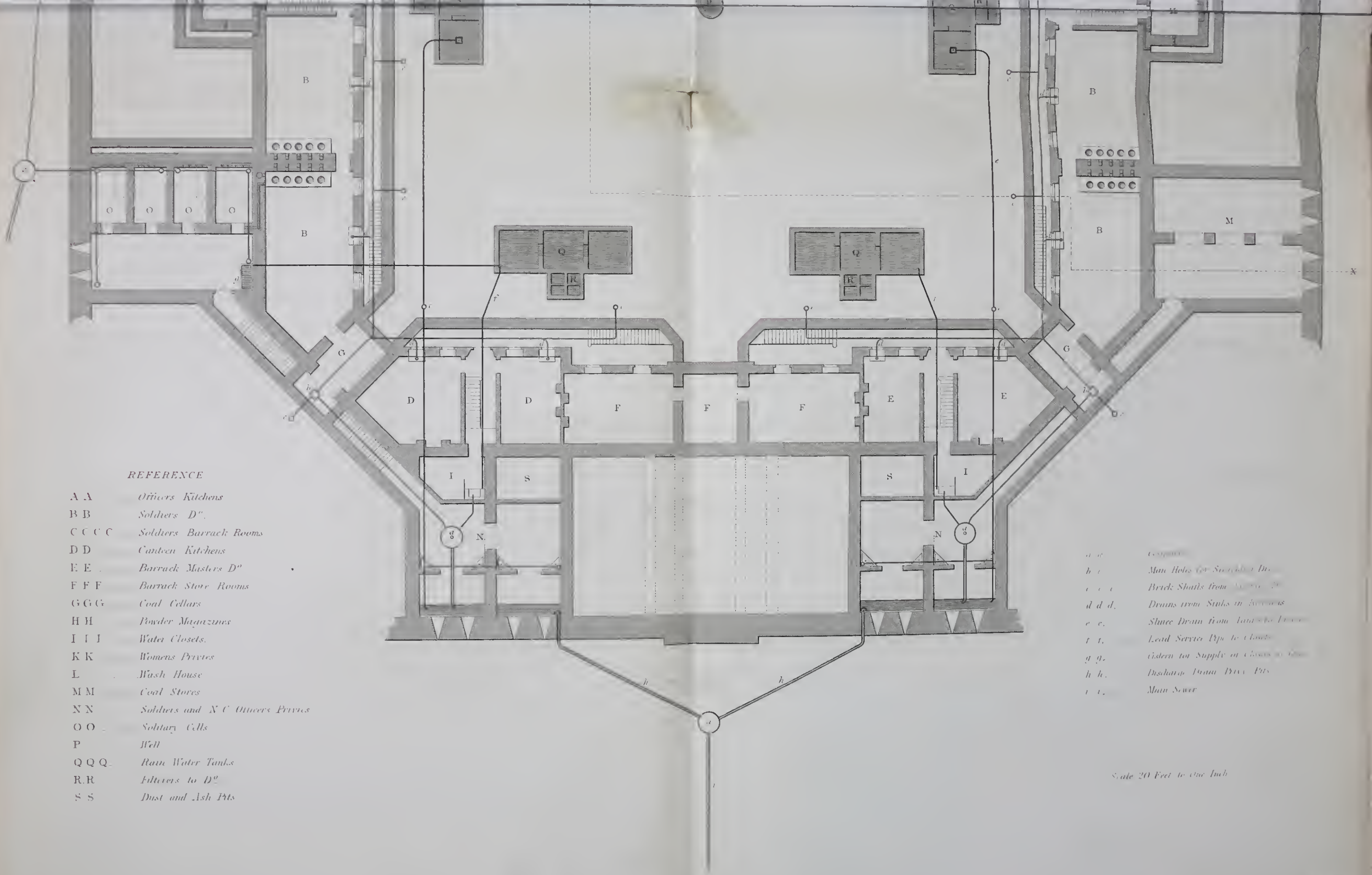
Plate IX. is a section through the building and interior elevation of the officers' range; the line of section passes through the magazine, basement story, tank, cooking kitchen, and casemate appropriated as barrack-master's coal-store; on it are also shown the heights of the different stories.

PLATE I

FORTIFIED BARRACK, PEMBROKE DOCK

PLAN of BASEMENT FLOOR





REFERENCE

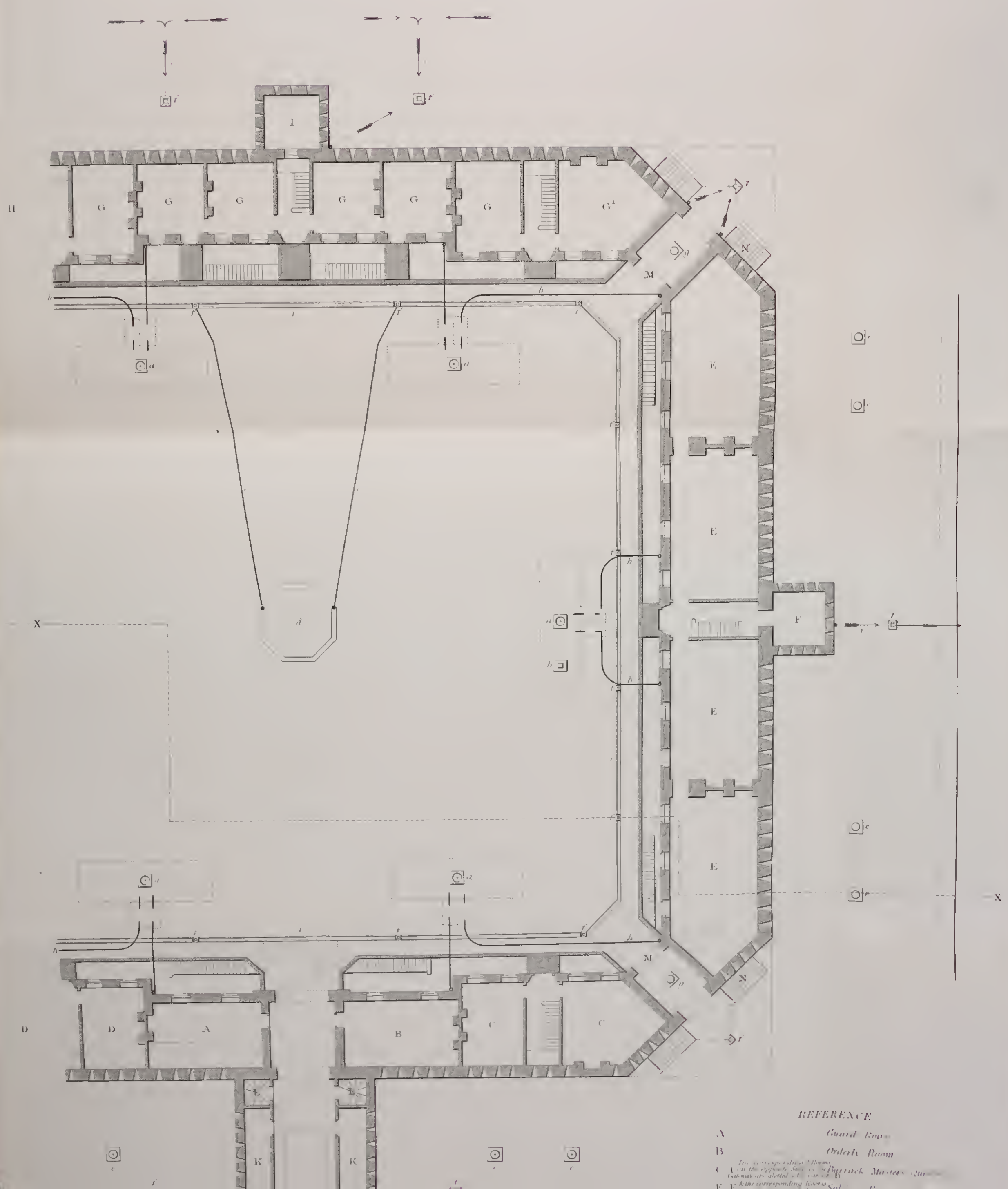
A A	*Officers Kitchens*
B B	*Soldiers Dº.*
C C C C	*Soldiers Barrack Rooms*
D D	*Canteen Kitchens*
E E	*Barrack Masters Dº*
F F F	*Barrack Store Rooms*
G G G	*Coal Cellars*
H H	*Powder Magazines*
I I I	*Water Closets.*
K K	*Womens Privies*
L	*Wash House*
M M	*Coal Stores*
N N	*Soldiers and N C Officers Privies*
O O	*Solitary Cells*
P	*Well*
Q Q Q	*Rain Water Tanks*
R R	*Filterers to Dº*
S S	*Dust and Ash Pits*

a a.	*Cesspools*
b b	*Man Holes for Searching Dr[illegible]*
c c c	*Brick Shafts from [illegible]*
d d d.	*Drains from Sinks in Barracks*
e e.	*Sluice Drain from Tanks to [illegible]*
f f.	*Lead Service Pipe to Closets*
g g.	*Cistern for Supply of Closets [illegible]*
h h.	*Discharge Drain Privy Pits*
i i.	*Main Sewer*

Scale 20 Feet to One Inch

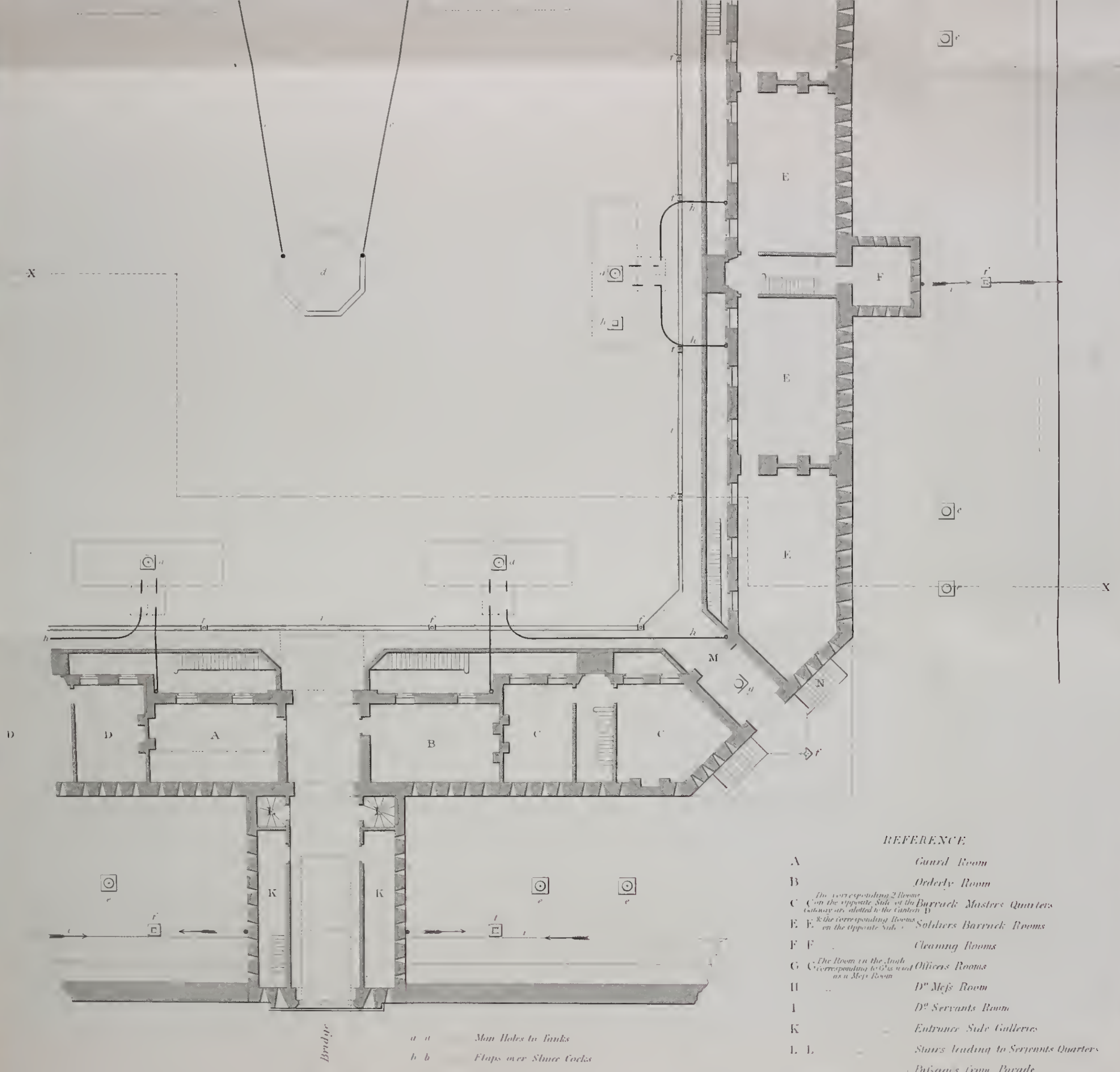
PROPOSED BARRACKS, PEMBROKE DOCK

PLAN of GROUND FLOOR



REFERENCE

A *Guard Room*
B *Orderly Room*
C *The corresponding Rooms on the opposite Side ... Gateway are allotted ... D* *Barrack Masters Quarters*
E *& the corresponding Rooms* *Sol...*



REFERENCE

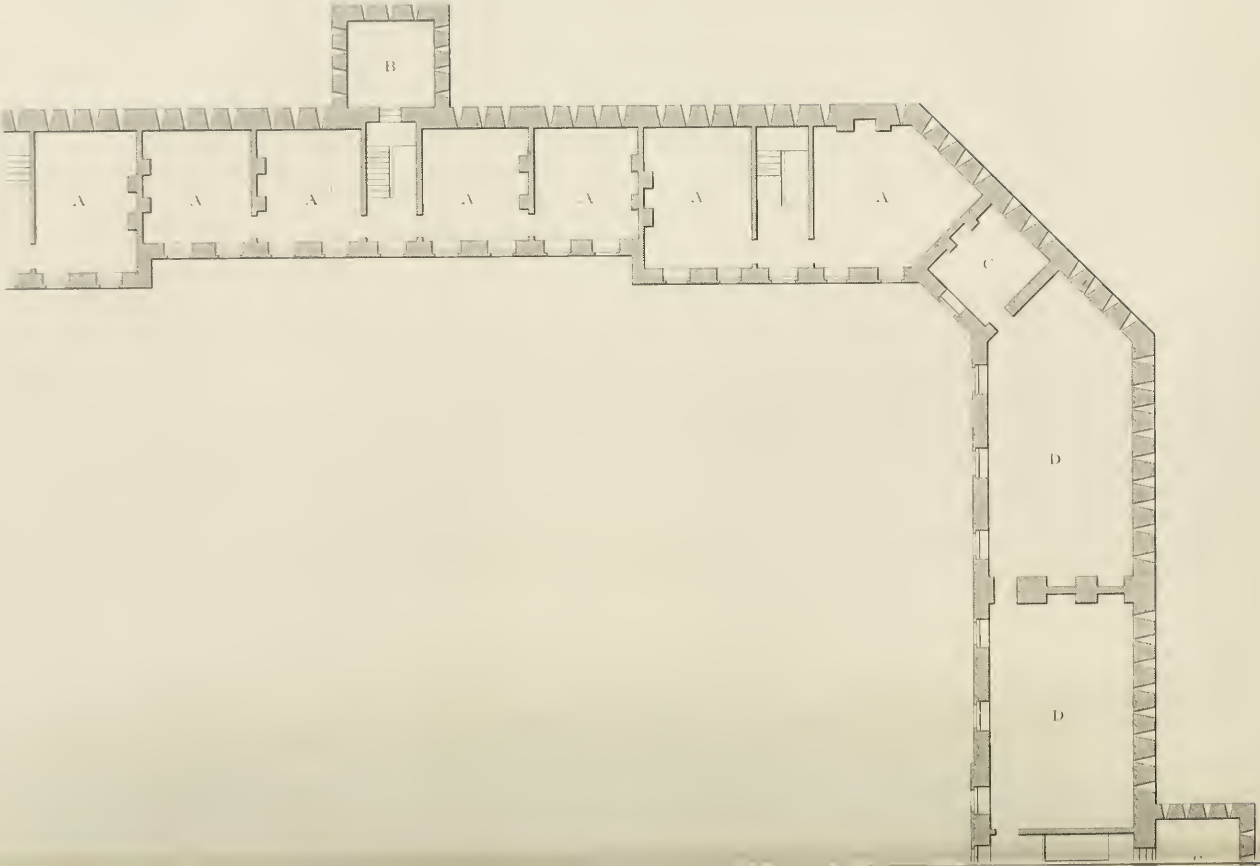
A		Guard Room
B		Orderly Room
C C	The corresponding 2 Rooms on the opposite Side of the Gateway are allotted to the Canteen D	Barrack Masters Quarters
E E	& the corresponding Rooms on the Opposite Side	Soldiers Barrack Rooms
F F		Cleaning Rooms
G G	The Room in the Angle corresponding to G is used as a Mess Room	Officers Rooms
H		D° Mess Room
I		D° Servants Room
K		Entrance Side Galleries
L L		Stairs leading to Serjeants Quarters
M M		Passages from Parade to Bastions
N N		Stairs to Casemates

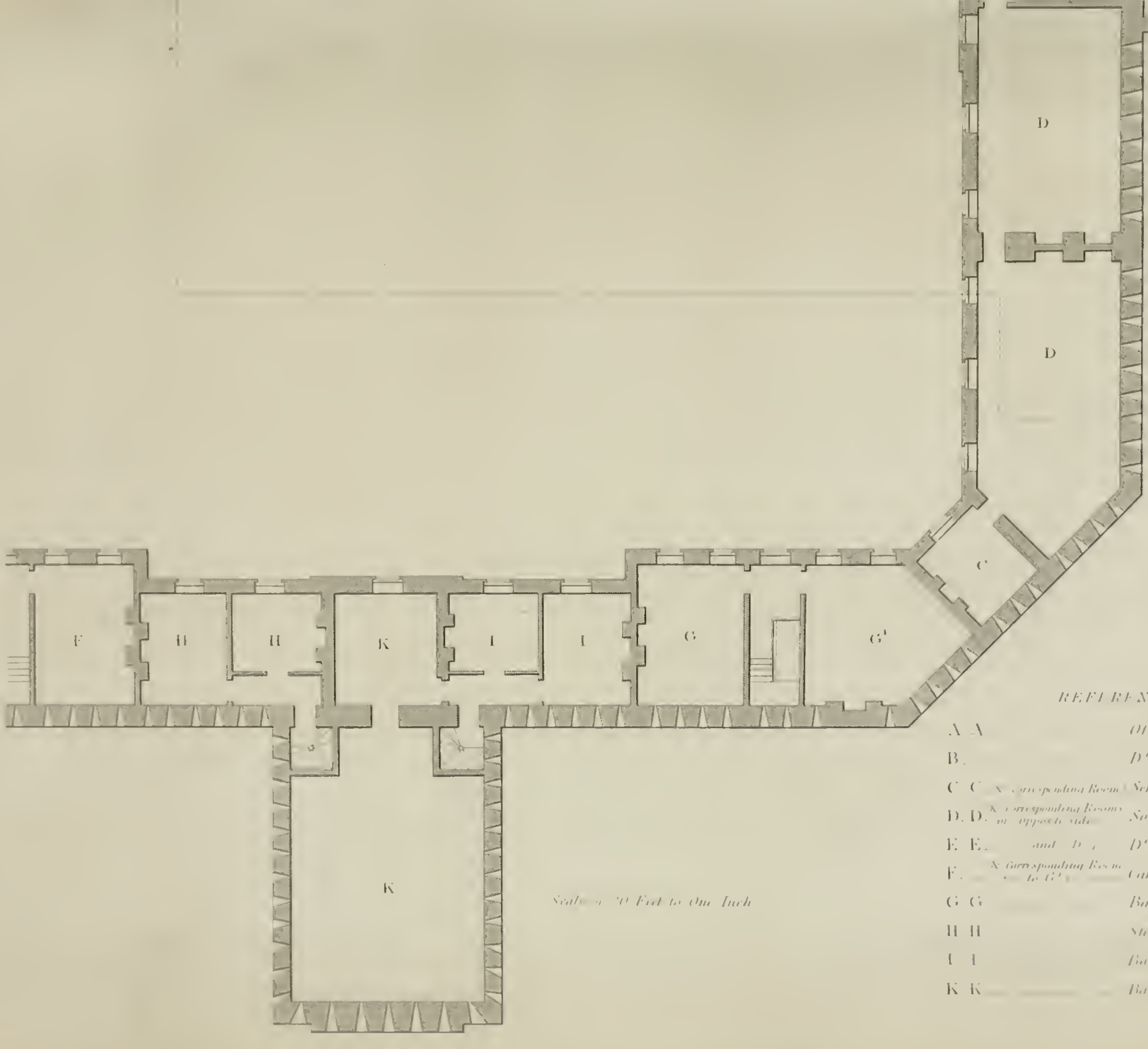
Scale 20 Feet to the Inch

a a	Man Holes to Tanks
b b	Flaps over Sluice Cocks
c c	Waste Drain from Pump
d	Pump
e e	Air Gratings to Casemates
f f	Surface Drain Gratings
g g	Coal Plates to Cellars
h h	Cast Iron Rain Water Pipes
i i	Surface Drains

DEFENSIBLE BARRACKS, PEMBROKE DOCK.

PLAN of FIRST FLOOR





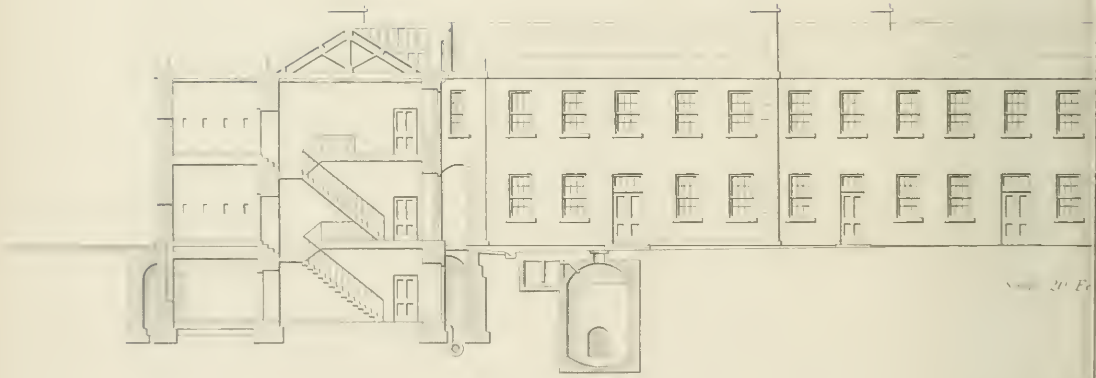
Scale of 20 Feet to One Inch

REFERENCE

A A		Officers Rooms
B.		Do Servants Room
C C	& corresponding Room	Serjeants Room
D. D.	& corresponding Rooms on opposite side	Soldiers Barrack R
E E.	and D .	Do Cleaning Rooms
F.	& corresponding Room to G1	Canteen
G G		Barrack Master Q
H H		Staff Serjeants R
I I		Barrack Serjeant
K K		Barrack Store D

FORTIFIED BARRAC

SECTION on the line XX, Shewin



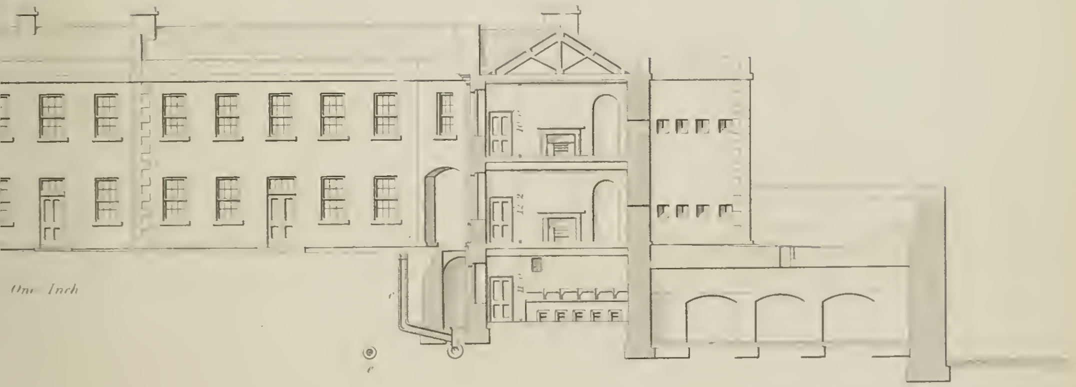
Scale 20 Fe

Drawn from

Shewn

, PEMBROKE DOCK.

ELEVATION of Officers RANGE



One Inch

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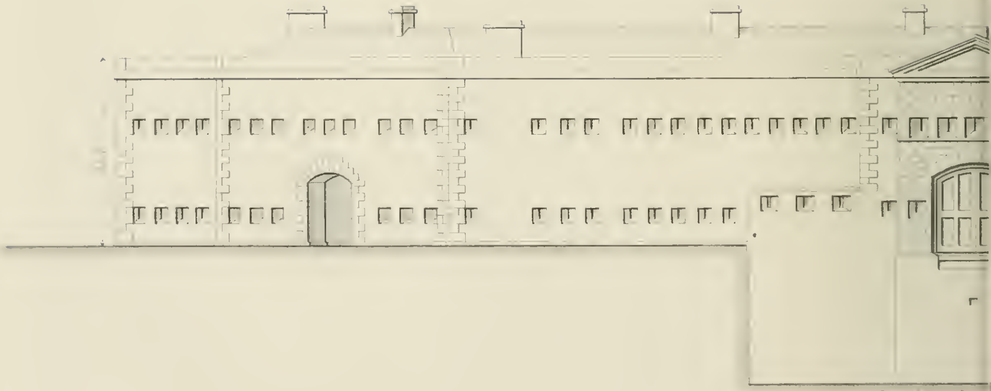
FORTIFIED BARRACK

OUTSIDE ELEVATION



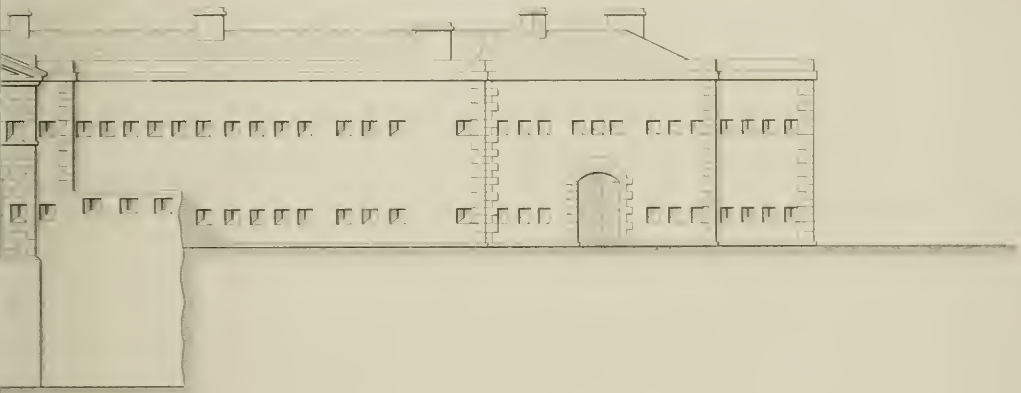
Scale of Fe

[illegible]

[illegible]

PEMBROKE DOCK.

ENTRANCE FRONT



Feet

[illegible]

[illegible]

Plate X. is an elevation of the entrance range and principal gateway: on it is marked the height of the external wall, and also the positions of the loopholes on the ground and first-floors of that range.

The barrack was commenced in 1842, and will be completed in the autumn of the present year.

W. Faris,
Captain, Royal Engineers.

Pembroke Dock,
10th March, 1845.

VI.—*Description of the Machinery used in the Manufacture of Cannon, at the Royal Arsenal, Woolwich.*

In no department of practical science has there been a more rapid advancement, during the past thirty years, than in the construction of machinery. While many causes have operated in producing this result, there is one agency which, from its apparent simplicity, we are apt to overlook, but which has been the chief instrument in accomplishing so remarkable an improvement, namely, the introduction of the sliding-rest principle.

Before the invention of this admirable contrivance, every separate piece of work had to be performed by manual dexterity. In the process of turning, the tool was held and guided by the hand, which was ever liable to err; and in the production of any other form, the tedious operation of the chisel and file had to be resorted to; and while the work done was very imperfect, it was necessarily most expensive.

By this principle we are able to produce the smallest, or the most ponderous piece of work, with equal facility and mathematical precision. The tool, instead of being held by the workman, is held by an iron hand not liable to err, while the attendant, instead of exerting his physical powers to the utmost, as he previously had to do, even in producing the simplest kinds of work, has now only to direct it by his skill, and in most cases even the guiding of the tool is not left to his hand, but is regulated by the machine itself, so that the operation, as far as the workman is concerned, is entirely mental.

And not only is it in the turning lathe that the advantages of this principle are so conspicuous, but in all our tools and machines, and nowhere are its beauties more splendidly developed than in the planing machine. By this machine we are able to produce the most perfect surfaces, whether horizontal, vertical, angular, or parallel, and with a facility and accuracy which, before its introduction, were never dreamt of; without it, there are many parts of the machinery about to be described that could not have been executed.

The machinery and tools employed in the manufacture of cannon, in the Royal Arsenal, have been constructed and erected by Mr. Napier, of London, within the past three years.

Previous to that time the manufacture was carried on in the most primitive manner. The boring mills or lathes which came from Holland about eighty years ago were in separate buildings, to each of which was attached a four-horse mill; upon the end of the shaft which brought the motion from the mill was a square box or chuck; into this box fitted a square, cast upon the gun behind the cascable. The muzzle of the gun ran in a circular collar plate, which was kept firmly in its place by means of iron bolts, connected to a strong foundation of iron-work and masonry. In the process of boring, the bit was forced into the gun by means of an endless screw, with rack and pinion, which was moved by a man or boy, while the laborious operation of turning was effected entirely by the hand tool: when bored and turned, the gun was put on a carriage, and taken to another building to be vented.

Here it was placed on blocks of wood while the several holes were drilled, which was performed by two men with a crank brace drill, the pressure being communicated from heavy iron weights placed above. The copper vent was drilled in a lathe, one end of the bolt on a centre, the other in a collar plate: the motion was given by two men on a fly-wheel, while the drill was held in the hand of another workman. In the same lathe the vent was turned and the screw cut upon it, both operations being performed by hand. When the copper vent was screwed into the gun, the projecting part inside was wrenched off by the workmen with a half-round bit: the gun was again put on a carriage, and taken to another building to be trunnioned.

When here, it was placed on blocks of wood, with the trunnions in a vertical position; one of the trunnions was then set off, and about a quarter of an inch of it brought to the proper size by the chisel and file. Upon this was placed a circular box, with a cutter fixed on the under side of it; on the other or upper side was fixed a vertical spindle, which received pressure from heavy iron weights hung above it. Long levers were now attached, and two or three men kept walking round and round until this part of the trunnion was completed; the extreme end of the trunnion being finished by chisel and file. The other trunnion was then turned up, and the same operation performed upon it; after which the gun was again placed on a carriage, and taken to another building to be finished.

Such was the tedious, rude, and imperfect system in use until about four years ago, when the necessity of a change was rendered manifest to the then Master-General of the Ordnance, the late Lord Vivian, who directed the Inspector of Artillery (Lieut.-Colonel Dundas) to submit for his consideration such plans as he should, under the circumstances, deem necessary; and the machinery then ordered, with very material and important additions authorised by Sir George Murray and the present Board of Ordnance, and other necessary machines constructed in the establishment, are now to be described.

The prime mover is an expansive and condensing steam engine of 12-horse power, which may be worked at a pressure of 30 ℔s. to the square inch, if required: it has two cylindrical boilers, only one of which is used at a time. The power is transmitted from this steam engine by a large strap passing over the drum (Y), and over a corresponding drum on the main shaft, which distributes the power over the factory, a general plan of which is given on Plate XI.

Plate XII. gives front and end elevations of a locomotive or travelling crane. The same letters in both figures apply to the same parts. The crane travels on a railway of cast iron (A), which extends the length of the building above the centre of the lathes.

The rails are supported or hung by bolts (*a*) to a strong wooden beam (T).

The framing of the crane consists of two sides (B) of cast iron, connected together by four cross stays of wrought iron, with nuts on the outside. The gun or weight to be lifted is slung in the hook (C). The double chain (D) winds round the crane barrel (E); upon one end of the barrel axle is keyed the large wheel (F), which gears into a pinion of seven teeth, but which is not seen in the drawing, the pinion being keyed on the same spindle as the wheel (G), but on the other end of it. The wheel (G) gears into the pinion (H), seen in fig. 2. This pinion, together with the chain-wheel (J), is keyed to the spindle (K), which goes through the barrel axle, and is retained in its place by a pin and washer on the other end.

Over the chain-wheel (J) passes an endless chain (L), hanging within 4 feet of the floor, so as to suit the height of a man: when the gun or weight in the sling requires to be raised or lowered, motion is given to the chain-wheel by pulling the endless chain (L). The wheel (J) acts as a fly-wheel, and when once brought to a good speed it, will continue running for some time: in the act of lowering, when motion is once given to it, and if there is a heavy weight in the sling, it will descend of course by its own gravity, but with a very gradual and easy motion, being retarded by the accelerated speed of the fly-wheel. A man can with ease lift 30 cwt. 9 inches in a minute; but, as by the unalterable law in mechanics we cannot have power and speed both, this powerful crane is necessarily a slow one; though, for the particular purpose for which it is used, that is its chief recommendation, for in putting the guns into the lathes or machines, the utmost caution is required to prevent them striking with violence any of the parts, and so damaging them; and for this purpose this crane is peculiarly adapted.

The brake (M) goes over the outside of the chain-wheel (J); it is made of strong hoop iron. To prevent it from rubbing on the periphery of the wheel, the rod (*m*) which is connected to the spindle (*n*) is kept up by the lever (*d*) with the weight (*e*) on the end of it; this lever is keyed to the spindle (*n*). To the other end of the lever is attached a cord (*c*), by pulling which the brake is made to bear hard on the wheel, and instantly to stop its motion.

The small chain-wheel (O) runs loosely on the spindle (*n*); on the boss of this wheel is keyed a spur-wheel (*p*) which gears into the pinion (*r*); the pinions (*r*) and (*s*) are both keyed on the same spindle (*t*). The pinion (*s*) gears into the rack (*v*), which extends the whole length of the railway. Over the chain-wheel (O) passes the small endless chain (N), which is prevented from slipping by small pins inserted in the wheel; and by pulling the chain (N), locomotion is given to the crane as may be required: the crane runs on four wheels or rollers (P), on the flanges of the railway.

To render the description of the machinery more distinct, let us take a gun in its rough state, as it comes from the foundery, following it through its various operations, and describing the machines as they are required to perform their several parts.

Guns are cast solid, in a vertical position, with the breech downwards; upon the muzzle or upper end the mould is prolonged from 3 to 4 feet, for the purpose of increasing the density in the lower part of the metal, feeding the shrinkage, and allowing the sullage or any spurious substance to rise to the surface.

This elongation is technically called the dead head.

When a cast of guns (generally eight or ten) comes from the foundery, the first operation is to cut off the dead heads. This is done in one of the boring and turning lathes. On the breech of the gun, beyond the button of the cascable, is cast a round stud about 3 inches in diameter, and 4 or 5 inches long. This stud is for holding the centre upon which the gun revolves, and upon which is fixed the carrier whereby the gun receives its motion.

The gun is lifted by the crane into the lathe. The stud (*a*, fig. 1, Plate XIII.) is inserted into the box chuck (*b*). This chuck is fastened between the four jaws of the face plate (A), which is screwed on the end of the lathe mandril; the jaws (*c*) are moved by separate screws, so that the box chuck can be shifted on the face plate until the body of the gun is brought to truth. To keep the gun in its place, and to give motion to it, a pair of clutches (*d*) are fastened on the neck of the cascable, and through which the bolts (*e*) connect the gun to the face plate.

Fig. 2 is a front elevation of the head or frame, on which rests the muzzle, both in this and in the subsequent operation of boring. A is a section of the lathe bed, of cast iron; B the collar head or frame, made of gun-metal; C the slide-rest frame; *a*, *a* are two steel plates fastened on the slide (D), which is the collar in which the muzzle runs, and is in the form of the letter V. This slide is made to rise or fall by two screws working simultaneously, so as to bring guns of different diameters into a horizontal position; the screws are at the back of the frame, and the handle to move them underneath.

Previous to the gun being put in the lathe, this head or frame is shifted 2 or 3 feet out of the way by means of a rack and pinion (*b*), and when the gun is apparently about its situation, made to slide back to its place; the muzzle is laid in the collar with the dead head projecting over. The tool (*c*) is fastened in the slide-rest by the pinching screws (*d*); the pressure to cut is given by turning the wheel or handle (*e*). The tool is about $\frac{1}{4}$ inch in width at the cutting part, and rather thinner behind, to enable it to clear itself.

The tool is shown commencing the cut; the workman continues to turn the handle, and to force the tool towards the centre, until the head drops off, which it generally does when within $\frac{3}{4}$ of an inch of the centre.

To prevent the block of metal damaging the lathe by its fall, a log of wood is laid across the bed of the lathe, about 1 inch under the head, upon which it falls. The operation of cutting off the head generally requires about twenty minutes.

The gun is now ready for the centering machine, the object of which is to find the exact centre of the mass of metal, and there to drill a conical hole at both ends of the gun, which are the centres upon which the gun is turned. Fig. 3 is a plan of this machine: A is a cast iron bed, resting on the three legs or standards (B); the top of the bed is a ∧ and flat, correctly planed, and forms a true surface for the different parts to sit or slide upon; C C are two saddles or frames, resting on the bed, and fastened to it by the bolts (*h*); each of the frames has three slides, which, by turning the handle (*i*), slide to or from the centre, and are equally distant from it in every position. Fig. 4 is a side elevation; C is the saddle or frame in which are the two horizontal slides (*k*); to the saddle (C) is bolted the frame (D), which carries the vertical slide (*q*): *l* is a shaft or spindle, working in gun-metal bearings; upon this shaft are cut two screws, the one with a right-hand thread (*m*), the other with a left-hand thread (*n*): *o o* are two brass nuts, working on the screws, and fitted into the horizontal slides. Now, by turning the handle (*i*), the two slides must move in opposite directions, the right-hand thread moving the one way, while the left-hand thread moves it the other. In the frame (D), which contains the vertical slide, there is a screw (*p*) with a right-hand thread, and of the same pitch as the two others. On the top of the screw is keyed a bevel pinion, gearing into another pinion with an equal number of teeth, keyed on the spindle (*l*); *r* is the nut on the screw, and fitted into the slide (*q*). By turning the handle (*i*) a motion is given to the screw (*p*).

As the pinions contain the same number of teeth, every turn of the horizontal screw gives a corresponding turn to the vertical; and as the three screws have the same pitch, namely, four threads to the inch, the turning of the handle makes them all approach to or withdraw from the centre simultaneously.

E, E, fig. 3, are two hand-drilling machines, resting on the bed (A), and fastened to it by the bolts (*h*); *s* is the spindle in which is fitted the drill (*t*): by the fly-wheel and handle (F), motion is given to the spindle. The boss of the fly-wheel is let $2\frac{1}{4}$ inches into the cylinder (*u*), and kept in its place by a steel pin. The hand-wheel (*v*) is for feeding the cut.

Fig. 5 is a section of this part of the machine; a screw is cut in the boss of the wheel (*v*), into which is fitted a corresponding screw, that slips loose upon the spindle; along the outside of this screw a groove is cut, into which is inserted a key that is fast in the cylinder (*u*): this key is to prevent the screw from turning while the wheel (*v*) is turned. The back part of the spindle is smaller than the drilling end, which gives a shoulder to the screw to press upon, while a pin through the spindle at the other end of the screw serves to bring it back again. A key let into the end of the spindle slides in a groove in the boss of the fly-wheel, and thereby receives its motion.

To centre a gun with this machine, it is only necessary to place it between the slides (*k*), and turn the handles (*i*) until the horizontal slides grip the gun, which brings the centre of the mass exactly opposite the centre of the drill.

The drilling heads are now brought forward, the fastening bolts are tightened, the workman with his right hand turns the fly-wheel (F), and with his other hand gently moves the hand-wheel (*v*) which feeds the cut. The whole operation, including putting the gun into the machine and taking it out again, may be accomplished in less than a quarter of an hour. (This machine was made in the establishment.)

The gun is now ready for the boring and turning lathe; a carrier is securely keyed upon the stud, and with the crane it is lifted into the lathe and placed between the centres.

In describing the various operations, we are obliged to use many technical terms; not that it is absolutely necessary, but it is as well that those who interest themselves in any subject should understand the terms by which that subject would be explained to them by those immediately concerned in it.

The centres of a lathe are those two points upon which the article revolves, or more generally, as in the present case, the one centre revolving with the work, while the other is stationary.

Plate XIV. gives a plan of the boring and turning lathes. A is a strong and massive bed of cast iron, resting on the floor of the building; the bed is cast in two pieces, and firmly joined in the middle. The top surfaces of the bed form a Λ and flat, and are accurately planed, so that the different parts of the machine which rest upon the bed have the same relative position to one another in any situation and without any adjustment. B is the spindle or mandril of the lathe; it runs in gun-metal bearings or pillow blocks of beautiful construction. The principal bearing (*a*) rests on C, an elegant yet substantial pedestal of the same metal. D is the turning saddle, on which is placed the turning and planing slide-rest (E); F is the collar frame, in which runs the muzzle of the gun; G is the boring apparatus; *b*, *b*, upon the shaft or axle (*c*), are the fast and loose pulleys, round which passes the strap that brings the motion from the main shaft. The fast pulley is keyed to the axle, while the other runs loosely upon it, and carries the strap when the lathe is in a state of rest.

Of all the methods which have been invented for disengaging and re-engaging machinery, there has been none to equal the simple, yet beautiful, contrivance of the fast and loose pulley. Unlike all the methods in use previous to its introduction, it is entirely free from shock; and in all machinery where the state of motion is not uniform, it is now universally used. The motion is conveyed to the lathe mandril through the bevel and spur-wheels. The pulley (*d*) on the mandril is for conveying motion by a strap to the pulley (*e*), which is keyed on the end of a shaft (H), extending to the other end of the lathe, for the moving of the boring apparatus. On the end of the shaft (H), and beyond the pulley (*e*), a small bevel pinion is keyed, which gears into a bevel-wheel on the cross shaft (*f*); this shaft carries the motion to the turning. On the shaft (*g*) are two bevel-wheels, gearing into the small pinion on the end of the cross shaft (*f*). The object of having the two wheels is to change the direction of the motion: when the slide-rest is required to move towards the right hand, the one wheel is slipped into gear, and when the opposite way, the other. When the shaft is not required in motion at all, neither of the wheels are in gear. A longitudinal groove is cut along the shaft (*g*), upon which slides a pinion with a corresponding key in it; this pinion is connected by a strap to the saddle (D), so that wherever the saddle may be placed, the slide-rest will receive a motion. The motion for turning is conveyed through the wheels (*h*) to the screw (*i*), which moves the slide-rest (E). The bed (I), upon which the rest slides, is a separate casting from the saddle, and may be set at any angle, either for turning or planing. This bed is planed in the form of a dovetail, upon which the slide-rest is fitted, provision being made for tightening the rest as it gradually wears. The handle (*j*) is for moving the slide-rest to the right or left; the other handle (*k*) is for the transverse slide, that is, for advancing the tool to take a deeper cut.

That part of the gun which lies between the trunnions of course cannot be turned in the ordinary way. In turning, the gun revolves about twenty-five times per minute, or thereabout,—that depending on the size of it,—while the slide-rest travels very slowly; but in the process of planing or cutting the parts between the trunnions, the slide-rest is made to slide longitudinally the length of the part to be planed, at about forty strokes per minute, while a motion, slowly advancing towards the tool, is given to the gun. K is a lever, keyed on a rocking shaft (L), which goes through and works in the bed of the lathe. On the top of the lever at *l*, there is a vertical slot, in which slides a stud or pin, fastened in an arm of the wheel (*m*), so that the rotation of this wheel makes the lever oscillate backwards and forwards a space in proportion to the radius of the stud in the wheel. There is a slot in the arm, so that the stud may be shifted, to enable the workman to make the slide-rest travel the distance he requires.

When the lathe is planing, the wheel (*n*) is put into gear with (*m*), and the large bevel-wheels are disengaged. The slide-rest is disconnected from the screw (*i*); a connection is formed between the rocking lever and the slide-rest at *o o*, by means of a double connecting rod, which can be drawn out and adjusted at any length. To produce the slow motion in the gun while being planed, *p* is a vertical lever, keyed on the end of the rocking shaft (L); *q* is a worm shaft, that goes through the bed and under the worm-wheel (M), which is keyed on the lathe mandril; upon the worm shaft, there is a short screw, or worm, which gears into the worm-wheel while planing, and is disengaged when boring or turning. On the top of the lever (*p*) there is a pallet (*r*), which falls into the ratchet-wheel on the end of the worm shaft. As the lever (*p*) is keyed on the end of the rocking shaft, it of course vibrates with it, and therefore gives a motion to the ratchet-wheel, the pallet slipping over the teeth the one way, and carrying the wheel with it the other. The stud which carries the pallet is fastened in a slot in the lever, so that it can be set to take any number of teeth, and, of course, giving a greater or less motion to the gun. The handle on the end of the worm shaft is for bringing back the gun by hand, to take a fresh cut.

There are several projecting parts on a gun besides the trunnions, viz., the vent-field, and lump for the tangent sight, a dispart lump, and, in some cases, a loop at the cascable.

In the turning of those parts, the tool has to be removed very quickly out of the way, until the projecting part is past, and then as quickly brought back again, so that no space may be lost on either side of it. A provision has therefore been made in the slide-rest for this operation, but which, as yet, has not been used with great advantage. In the slide-rest, besides the transverse slide worked by the handle (*k*), there is a double transverse slide, not used in ordinary turning, but only for the jumping motion. This slide is not worked by a screw, but by a combination of levers in the interior of the slide-rest. The principle of action is similar to the elbow joint in the human arm. When the levers are in a straight line, and therefore in their strongest position, the tool is thrown in, and cutting, while the bending of the levers draws it out again. On the left-hand side of the slide-rest, at *s* there is a flange, with two studs fastened in it:

this flange is keyed on an axle, in connection with the levers above referred to. N is a hollow shaft, with a crank (O) on the end of it. The flange (s'), with the two studs fastened in it, is part of another shaft or rod, with a longitudinal groove cut in it; it fits in the hollow or crank shaft, and slides easily out or in, but is prevented from turning in it by a key fastened in the crank shaft, and fitting into a groove in the other.

Upon the extremity of the crank there is a friction roller on a stud. On the side of the wheel (P), and near to the teeth, two dovetail grooves are turned in it, for the reception of bolts. These bolts are for fixing cams on the side of the wheel, at any part of the circle.

In using this part of the apparatus, a connection is formed between the flange (s') on the shaft, and the other flange (s) on the slide-rest: two cams are fastened on the side of the wheel (P), opposite the part of the gun to be leaped over; the one cam strikes the friction roller on the crank, and throws the slide-rest back; the other cam instantly strikes it on the other side, and throws it forward, where it remains cutting, until the throwing-out cam returns. It will be perceived, that the jumping motion may be in action at the same time with the self-acting turning motion, which is the case for parallel or taper turning; and if a curve has to be formed, the other transverse slide is brought into play by the workman with the handle (k); all the three operations working in beautiful harmony, and the boring going on at the same time.

We come now to the boring apparatus. Q is a strong frame of cast iron, resting on the Λ and flat of the lathe bed, to which it is firmly bolted by the bolts (r). G is the boring bed, or bench, on which slides the boring bar.

The boring bed is strongly built of mahogany, and firmly bound with iron bolts and plates. The parts where the bar slides, the ends under the advancing screws, and those places where there are fastenings, are strongly faced with gun-metal. The object of having the bed of wood is to avoid tremor. The boring bar (R) is the instrument on which the bit for boring is fastened. In forcing the bit into the gun, there is a great tendency to twist the bit and bar round with it: to prevent this, there are three strong cross heads (S), with a boss at each end, and a large boss in the centre for the pressing screw, on one of the end bosses; the cross head swivels on a stud, securely fastened in the bed. The object of having it to swivel is, that when the workman is taking out or putting in a bit, the whole thing may be turned round out of the way. The boss at the other end, that is, the end which comes to the front of the lathe, has an opening on one side, so that when the cross head is brought to its place, the boss clasps a stud, similar to the one on which it swivels. The pressing screws in the centre, which are wrought by the handles (*s*), do not press directly on the bar, but on an intervening plate, connected to the cross head.

As the boring bars differ in size, and as the boring bit always requires to be in a certain position in reference to the centre, it is therefore necessary that the boring bed rise or fall as the work may require. It is also necessary that the bed be quite level in every position. To effect this, there is a very beautiful contrivance, which is not seen in the drawing, but which I shall endeavour to describe.

The bed rests upon four large screws, at the points (*t*) in the frame (Q). Upon each of the screws there is a worm-wheel: their relative positions are shown by the dotted circles on the bed; by turning the worm-wheels, the screws rise or fall. Along the centre of the frame (Q), and between the worm-wheels, a horizontal shaft is placed; there is a worm or screw on each end of the shaft, and each worm gearing into two of the wheels. Now by turning this worm shaft, a motion is given to the four screws; and as the screws are of the same pitch, and the wheels have the same number of teeth, the whole must work simultaneously, and the bed is on the same level in every position. The small shaft on the frame (Q), with the handle at T, has a bevel pinion keyed on its farther end, which gears into a bevel-wheel, keyed on the worm shaft above referred to; so that the turning of the handle (T) raises or lowers the boring bed: *u* are the heads of large bolts, which fasten the bed to the frame (Q), when the workman has brought it to its proper position. U are the screws for advancing the boring bar: they have pinions keyed on their farther end, and get their motion from a pinion on the boss of the wheel (V), but not seen in the drawing. The wheel (V) may be wrought self-acting, or by hand; the handle (*v*) is for throwing the wheel out or into gear with the lathe.

As was observed before, motion is conveyed to the boring through the shaft (H), along which a groove is cut; a pinion, with a key corresponding to the groove, slides on the shaft. This pinion is connected to the frame (Q), so that wherever the frame is placed, it carries the pinion along with it. This pinion is connected with a bevel-wheel keyed on the bottom of a small upright shaft, with a longitudinal groove cut in it. The lower end of the shaft is connected to the frame (Q), while its upper slides in a socket in the under side of the boring bed: a pinion on the top of the upright shaft is connected to the bed, so that the raising or lowering of the bed interferes not with the motion.

This upper pinion gears into a bevel-wheel on a short horizontal shaft under the boring bed; on the other end of this shaft there is a small spur pinion, which, by an intermediate wheel, gives motion to the wheel (V), seen in the drawing.

The handle (*v*) for throwing the self-acting boring motion out or into gear is the end of a lever, having for its centre of motion the boss of the spur pinion on the end of the short horizontal shaft: upon this lever the stud is fastened on which runs the intermediate wheel, so that, as the lever works on the boss of the pinion, the intermediate wheel must always be in gear with it; but the raising or lowering of the lever or handle (*v*) connects or disconnects it with the wheel (V).

The method of shifting the turning saddle, the collar frame, and the boring apparatus, on the lathe bed, is by a rack and pinion; *w*, *w*, *w* are squares on the end of shafts, which go through to the other side, where they have pinions keyed. These pinions gear into the rack (W), which is bolted to the lathe bed. On the squares at *w* a handle in the form of a cross is placed, so that with comparative ease the workman may shift them as he requires.

Fig. 2 is the plan of a centre bar, which is used when the gun is first put into the lathe. The part (*a*) is fastened in the boring bed; the collar (*b*) rests in the V of the collar frame, and is kept down by the slide (*x*); *c* is a steel centre, on which the muzzle of the gun turns.

Such is but an imperfect description of this splendid tool, and, although its merits need no commendation, it is right to state, that the workmanship is of the very best description, that an exuberance of mechanical skill is displayed in all its details, and that it adds another laurel to its ingenious contriver, Mr. D. Napier.

When the gun is first put into the lathe, the centre bar is fastened on the boring bed, and the centre pressed gently into the corresponding centre of the gun. The base ring is first turned, because from it the workman takes all his measurements; he then turns and almost finishes the muzzle. The centre bar is taken down, and the muzzle of the gun is laid in the V of the collar frame, as seen in the drawing. A drill is sent a few inches into the gun; the drill is removed, and a small slide-rest fastened on the end of the boring bed, with which the hole made by the drill is brought to the size of the first bit. The slide-rest is removed, and the bit for boring entered in the hole made for it; the bar is pressed down, but not so tight as to prevent its sliding. The self-acting boring motion is thrown into gear, the lathe is started, and the workman attends to the turning.

Bit after bit is used in the same way, until the bore is brought to the proper dimensions, while the workmen generally contrive to finish the turning about the same time. When both of these operations are finished, the planing apparatus is put in motion, and the part is finished that lies between the trunnions. The gun is taken out of the lathe, and put in the trunnion machine.

Plate XV. is a plan of the trunnion machine. A is a strong and massive bed of cast iron, resting on the floor of the building; it is planed flat on its top surface. B is another bed of cast iron, somewhat similar to a lathe bed; it is planed both on its top and bottom surfaces, and firmly bolted to the bed (A). The top surfaces of the bed are in the form of two inverted V's, on which are fitted the saddles (C C). The screws (*a*) with the handles (*b*) are for adjusting the saddles with the gun, to bring it into its proper position; *c* are handles for adjusting the vertical slides (*d*); *e* is a cone centre that fits into the centre of the stud in the gun upon which it was turned; *f* is a cone that fits into muzzles of various sizes: as the trunnions of most guns are under the centre, there is an index on the face of the vertical slides, (but which is not seen in the drawing,) whereby the workman can set the gun with the utmost accuracy: when the slides are at the bottom, or as far down as they will go, the axis of the gun is on the same horizontal line with the axis of the turning spindles (G), so that if the centre of the trunnion is $\frac{7}{10}$ths of an inch under the axis of the bore, the workman, by the handles (*c*), lifts the slides, and of course the gun, the required distance: *g* are the bolts for fastening the saddles on the bed, when the gun is brought to its proper position. D D are the turning frames, bolted to the large bed (A); they are set at right angles to the bed (B), and the spindles of the two frames are in a perfectly straight line.

The driving shaft (E) goes through the inside of the bed (A), and under the centre of the turning frames; on the driving shaft there are keyed two pinions which gear into the wheels (F). There are openings in the top of the bed (A), through which the teeth get into contact: *h* are sockets of gun-metal, on which are keyed the wheels (F); *i* are the bearings in which the spindle (G) runs. H are the frames, in which the turning tools are fixed; *k k* are the tools, shown with a cut; the pieces (*m*) on the other side are rubbers, which act as a stay to the tool, and to prevent tremor.

A groove is cut along part of the spindle (G), in which fits a corresponding key, fastened in the socket (*h*), so that the rotation of the wheel and socket gives a motion to the spindle, while the groove in the spindle allows it to move endwise, as may be required: the motion for feeding the cut may be wrought self-acting or by hand. J is the self-acting feeding motion, shown in gear: to throw it out of gear, and work by hand, it is only necessary to push the wheel (*o*) back to the head of the stud (*q*), and turn the handle: the manner in which the self-acting motion is produced is very ingenious. The end of the spindle (G), which is farthest from the turning tool, is bored out hollow; into the tube there is fitted a spring, with four arms that force outwards. This spring is keyed on the end of a small steel shaft, having a small steel pinion on its other end: this pinion gears into the wheel (*o*), which, by the long pinion keyed on its boss, gives a motion to the wheel (*r*). The wheel (*r*) is keyed on the end of a screw, which is connected to the spindle (G), and so gives it the forward motion. One great advantage of having the motion through the spring is, that when the tool comes to any place on the trunnion where it cannot get forward, the spring slips in the tube, and no mischief arises.

As was observed before, to disengage the self-acting motion, it is only pushing the wheel (*o*) out of gear with the steel pinion on the end of the spring shaft; and as the pinion on the boss of the wheel (*o*) is double the breadth of the wheel (*r*), it still remains in gear with *r*, so that the hand-wheel (*o*) retains a command over the spindle. K is a fly-wheel on the end of the driving shaft (E), by which the workman may turn the tool round by hand, when he requires to do so. L is the strap lever, by which the machine is thrown out or into gear. It is wrought by the handles (*n*). M are the fast and loose pulleys.

Before putting a gun into this machine, the workman divides off the distance of the centre of one of the trunnions from the base ring, and then describes a circle. The gun is placed between the centre and cone. The gun is adjusted with a spirit-level. He knows by the drawing how much the axes of the trunnions are below the axis of the bore, so by the handles (*c*) he raises the gun, setting it to the index as the gun requires: he then fixes a scriber where the turning tool is fastened, and by turning it round carefully by hand, he sees if the line it makes coincides with his former division; if it does not, the gun is shifted by the handles (*b*) until it is brought to its true position. The fastening bolts (*g*) are then tightened, and to prevent the gun from moving during the operation, it is wedged up underneath.

Both trunnions can be turned at the same time, the whole operation occupying from five to seven hours.

Nothing can exceed the accuracy by which guns are trunnioned with this machine. As the spindles are at right angles to a line drawn through the centre of the gun, the trunnions must be at right angles to the bore; and as the axes of the spindles are in a straight line, the axes of the trunnion must be in a straight line with one another.

When the guns are trunnioned, they are taken to the drilling machine to be vented.

Plate XVI. shows side and front elevations of the drilling machine, with a section of the spindle; the same letters in all the figures apply to the same parts.

A is a strong frame of cast iron, in one casting; it is bolted to the wall of the building by the four bolts (*a*), with wall plates on the outside. B are the fast and loose pulleys: on the same axle is keyed the cone pulley (C). D is a corresponding cone pulley, keyed on the same axle as the wheel (*b*). The object of having the cone pulleys is to obtain variety of motion; for example, a hole of $\frac{1}{4}$ inch in diameter would be drilled with a much faster motion than a hole of 2 inches diameter. By having the cone pulleys, the workman may have the motion that best suits his work, by shifting the strap on the proper division of the pulley. S is the strap which connects the two pulleys; the wheel (*b*) gears with the wheel (*c*); the boss of *c* is fitted into a socket or bearing (*d*), in the framing (A). In the spindle (*e*) which passes through the wheel (*c*) a longitudinal groove is cut: in this groove fits a key, which is fastened in the boss of the wheel (*c*), so that the rotation of the wheel gives a motion to the spindle, while the spindle is at liberty to slide up or down. The weight of the spindle is supported by a ball of cast iron (*f*), hung on the end of a chain (*g*), which passes over the pulley (*h*). The pressure to the drill is communicated by the fly-wheel handle (E). In the boss of the wheel (E) a screw is cut, through which passes a screwed socket (*i*), which fits upon the spindle. A groove is cut along the back of the screwed socket, in which fits a key, fastened in the framing (A), to prevent the screw from turning round, so that the turning of the fly-wheel (E) causes the screw to rise or fall; and as the screw (*i*) presses on the collar of the spindle (*e*), the screw and spindle rise or fall as the wheel (E) is turned, which is done by the hand of the workman: *k* is the apparatus for shifting the strap, from which are suspended the balls (*l*) by the cords (*m*), for throwing the machine out or into gear. The drill fits into a socket in the spindle at *n*.

We shall now describe the bed or frame in which the gun is laid in being drilled. The object of this machine is to afford accuracy and facility in placing the gun, in having the different holes drilled.

Plate XVII. gives a side elevation (fig. 1) of this machine, with part of the drilling machine above it. Figs. 2, 3, and 4, are different parts of the same: the same letters in all the figures apply to the same parts.

A is a bed of cast iron; the top surfaces are planed with dovetail edges; upon the bed are fitted the two slides or saddles (B and C). The slide (B) carries the body of the gun, while the breech rests upon C: each of these slides can be made to slide along the bed of the machine. Within the bed (A), and on each side of it, there is placed a horizontal screw, with a wheel (*a*) on the outer ends of them; into these gear other wheels (*b*), which are keyed on the boss of the fly-wheel handles (*c*). The screw passes through nuts in the slides. The handle and wheels seen in the drawing are for the slide (C), but those on the other side are exactly the same: by turning the handles (*c*) the slides pass along the bed as may be required.

On the slide (B) are two columns, working in transverse slides by the handles (*d*). The trunnions of the gun are laid into V's on the tops of the columns (see fig. 2). These V's are level, and at right angles to the spindle in the drilling machine; and as the trunnions are accurate and true, (as was shown before,) a line drawn at right angles to the axis of the trunnions, from the highest point in the circumference of the gun, would bisect the bore. When the gun is laid in the V's, the first object is to find the highest point: this the workman readily does, by the aid of a spirit-level for the purpose. Both at the breech and muzzle, a line is drawn, cutting the two points: upon this line he sets off the vent, and the hole for the tangent scale, and from it all other divisions in finishing the gun are taken. By the handles (*d*) of the transverse slides, this centre line is brought under the centre of the drill, and it now requires another kind of an adjustment. Although the holes have to be perpendicular to the trunnions, they are not so to the gun lengthwise; but at various angles for different patterns of guns, and in the same gun, the hole for the vent is at a different angle from the hole for the tangent scale: in drilling the former the breech is raised above the muzzle, while in drilling the latter it often is under it. This is accomplished by the drilling table (D), on the slide (C). The table is raised by the screw (*e*) underneath, working in a nut (*f*) in the slide (C). Near the top of the screw is keyed a bevel-wheel (*g*), in which gears a pinion, keyed on the same axle as the hand-wheel (*h*). At each end of the drill table (fig. 3) there is a strong socket (*i*), accurately bored. These sockets slide up or down on the studs (*k*) that are fastened on the slide (C). M is a V, fastened on the table, into which is laid the breech of the gun. A graduated plumb-level is applied to the muzzle, and the drill table is raised or lowered by the handle (*h*), until the gun is lying at the right inclination. When this is done, the workman turns the handle (*c*) of the longitudinal screw, and brings the centre of the hole under the centre of the drill lengthwise. The gun is now right, and the hole is drilled; both operations, including adjusting and drilling, occupying a very short time indeed.

Besides the holes for the vent and tangent scales, in many guns there is a breeching loop at the cascable, in a line with the trunnions. In drilling this hole, the trunnions are taken out of the V's, and the gun turned round, until they are in a vertical position. The gun is then placed in wooden bearings in the frame (F), which is bolted to the slide (B). F is of cast iron, and planed on its bottom and front surfaces; on its front are planed two vertical dovetail slots, for the reception of bolts to fasten the frame (G), which slides up or down as may be required. The frame (G, fig. 4) is composed of two vertical studs (*m*,) fastened in a roll plate (*l*). On one of the studs the cross head (H) swivels, and with an opening in the boss, at the other end of the cross head, it clasps the other stud. K K are two pieces of wood that fit between the studs. To place a gun in the frame, the cross head is turned to one side; the top piece of wood is lifted out, and the gun dropped into the other bottom piece: the top piece is again slipped in, the cross head turned round to its place, and the gun bound by the screw and handle (L), when the gun is brought to a true level by the drill table, and adjusted lengthwise as before, with the handle (*c*). It may be stated, that the drill table (D) can be used for ordinary drilling when not required for guns. The top surface is flat and level, and slots are provided to fasten the work by. (This machine was constructed in the establishment.)

When all the holes in the gun are drilled, it is taken out of the drilling bed, and laid on a pair of trestles. The first thing done is to prepare the hole for the copper vent: this is accomplished by hand with a series of screwing taps. The copper vents are made out of $1\frac{1}{4}$-inch round bolt copper. The pieces are cut off the bolt to the proper length by a circular saw, in a shaping machine. A number of the pieces are then fastened between two plates, on a planing machine, and have squares planed on one end of them; these squares fit into a chuck, in a small horizontal drilling machine. The other end of the copper runs in a steel bearing or collar. A boy holds a drill in his left hand, and with his other turns a screw that presses the drill into the metal. The hole is drilled right through. As the hole is small, ($\frac{2}{9}$ths of an inch,) the copper revolves at 770 revolutions per minute.

When as many pieces as are required are drilled, they are taken to a self-acting and screw-cutting lathe, to be turned and screwed: they are now ready for the gun. The vent is screwed into the hole by two men, with a powerful lever, fitted on the square of the copper vent; and when the vent is home to its place, the square is cut off.

When six or eight guns are advanced thus far, they are again put in the boring and turning lathe, to have the projection of the copper cut off inside the bore, and to have the chamber finished.

Although the gun seems now almost completed, it is a striking fact, that as regards men's time, there has more to be bestowed on it yet than in all the previous operations.

If we take, for example, a 24-pounder howitzer, for sea service: the cutting off the dead head, centering, boring, turning, planing, trunnioning, drilling, and venting, will occupy altogether from seven to eight days; but the time that will be required to finish what is comparatively small,—the loop, vent-field, sight, and the necks of the trunnions,—will be from eight and a half to nine and a half days; while the expense of tools, viz., chisels and files, is, to say the least, five times more than in all the previous operations. (Six days more will be occupied in engraving the gun.) The various parts that have to be removed and finished by the chisel and file are so very different in their shapes, that at first thought, it would appear almost an impossibility to make a machine to do this work perfectly and efficiently; but, on further reflection, these difficulties in a great measure vanish. A shaping machine for this very important purpose may be constructed, and we trust that before long this desideratum—the only thing now necessary to complete the machinery—will be supplied; and if so, we hope to be able, in a subsequent volume, to furnish the drawings and description thereof.

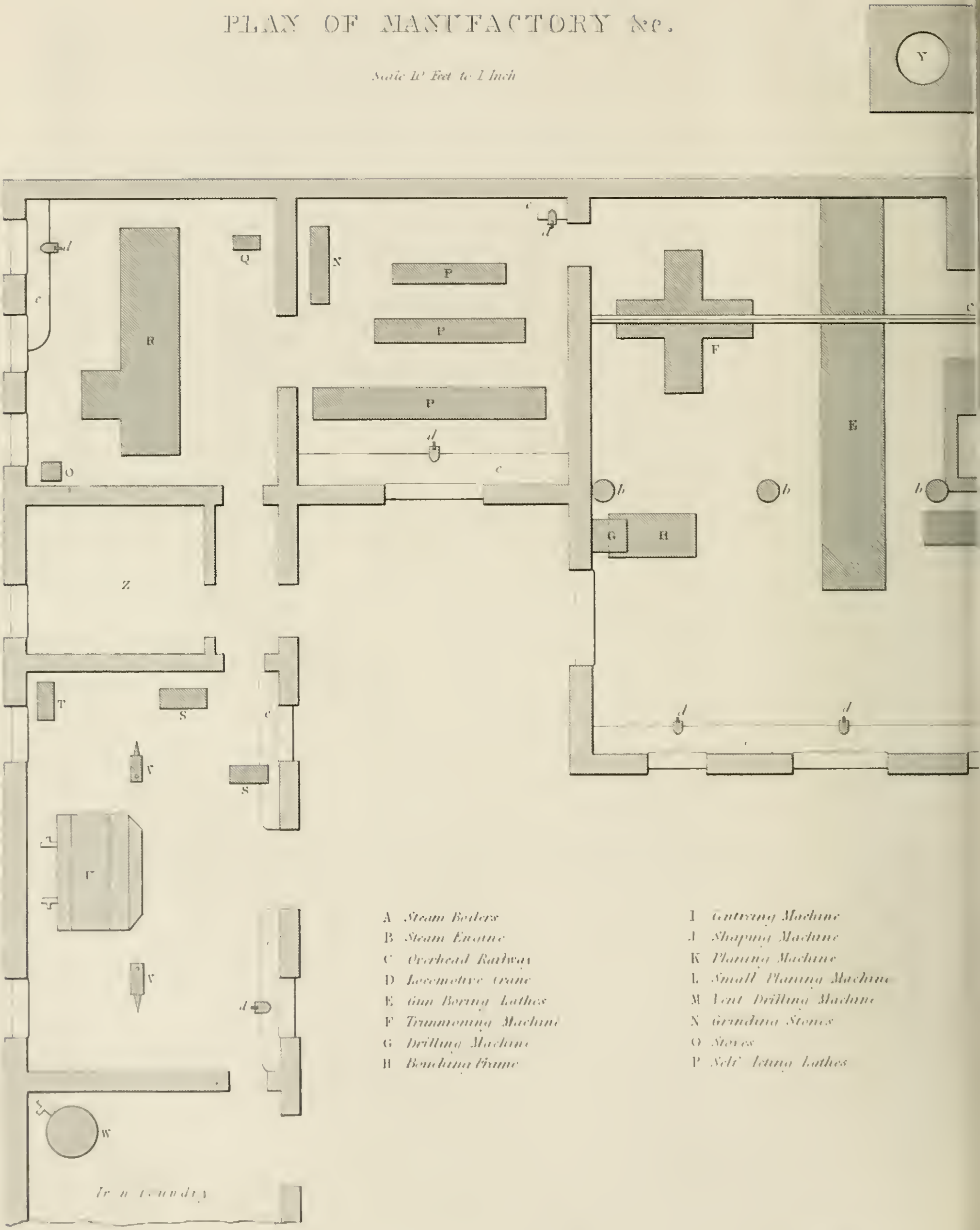
Before concluding, it may be stated, that besides the machinery more especially adapted and intended for the manufacture of cannon, there is a complete set of engineers' tools, as is shown in the plan of the factory, Plate XI.; so that any additions, alterations, or repairs to the machinery, may be effected on the premises; and at the present time (1845) workmen are there engaged in constructing granulating and breaking-down machines, for the service of the powder-mills at Waltham Abbey.

Adjoining the factory is an iron foundery and blacksmiths' shop; the fan for blowing the cupola and the forges being driven by the steam engine.

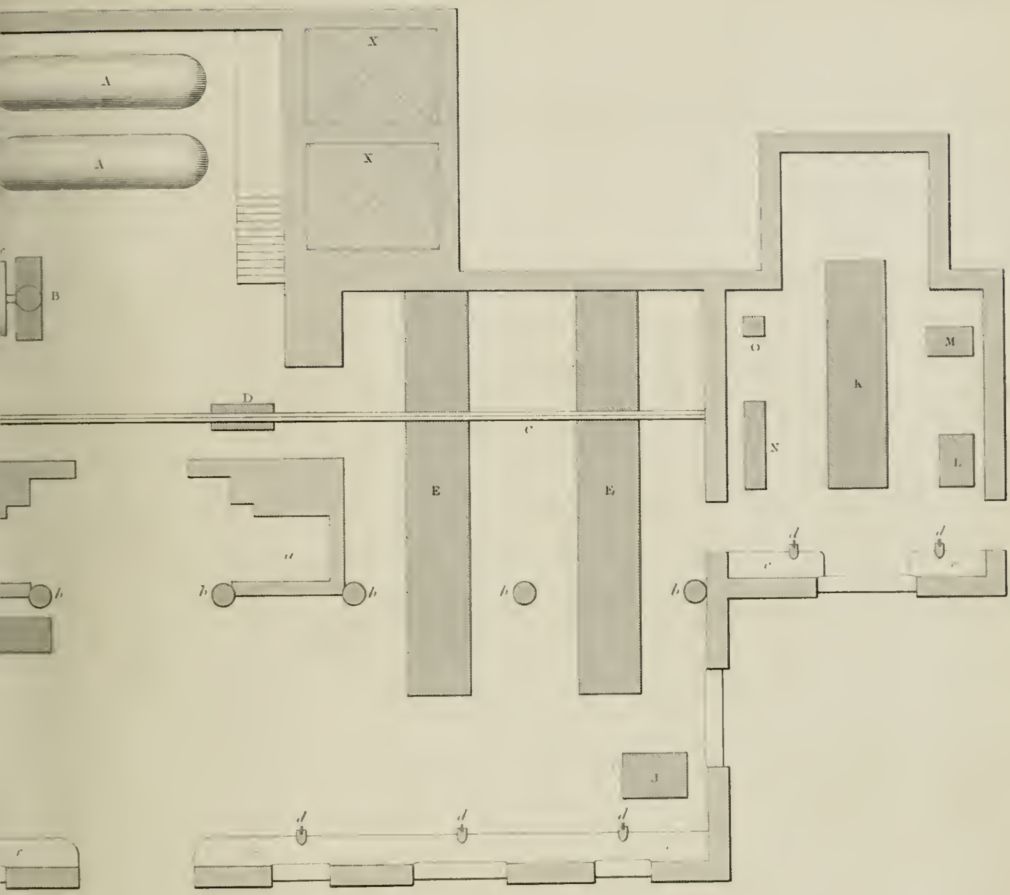
JOHN ANDERSON.

PLAN OF MANUFACTORY &c.

Scale 10 Feet to 1 Inch



A *Steam Boilers*
B *Steam Engine*
C *Overhead Railway*
D *Locomotive Crane*
E *Gun Boring Lathes*
F *Trunnioning Machine*
G *Drilling Machine*
H *Benching Frame*
I *Cutting Machine*
J *Shaping Machine*
K *Planing Machine*
L *Small Planing Machine*
M *Vent Drilling Machine*
N *Grinding Stones*
O *Stoves*
P *Self Acting Lathes*



Gutter Forming Machine
Large Lathe and
Wheel Cutting Engine
Polishing Lathes
Blowing Fan
Smiths Forges
Smiths Anvils
Iron Cupola Furnace

X Coal Vaults
Y Chimney Stalk
Z Engineers Office
a a Tool Stores
b b Iron Pillars
c c Work Benches
d d Vices
e Fly Wheel
f Drum of Steam Engine

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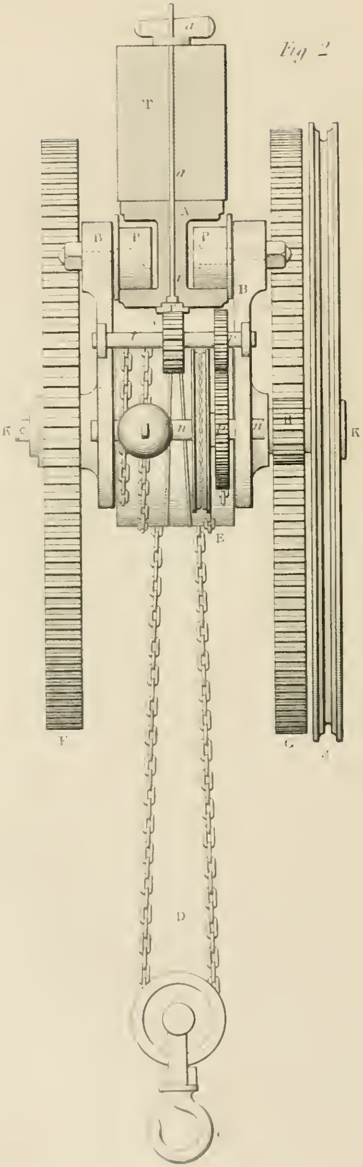
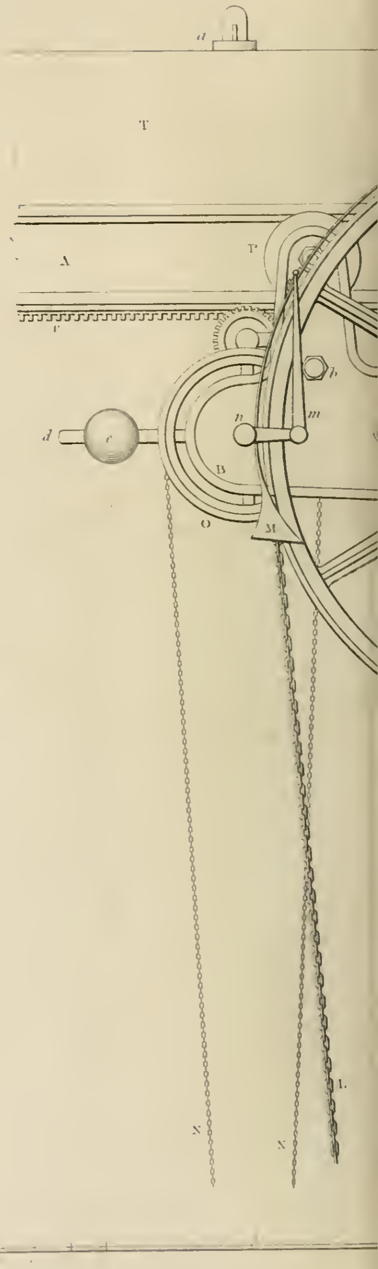
LOCOMOTIV

Fig 2





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CRANE, &c.

Plate XII

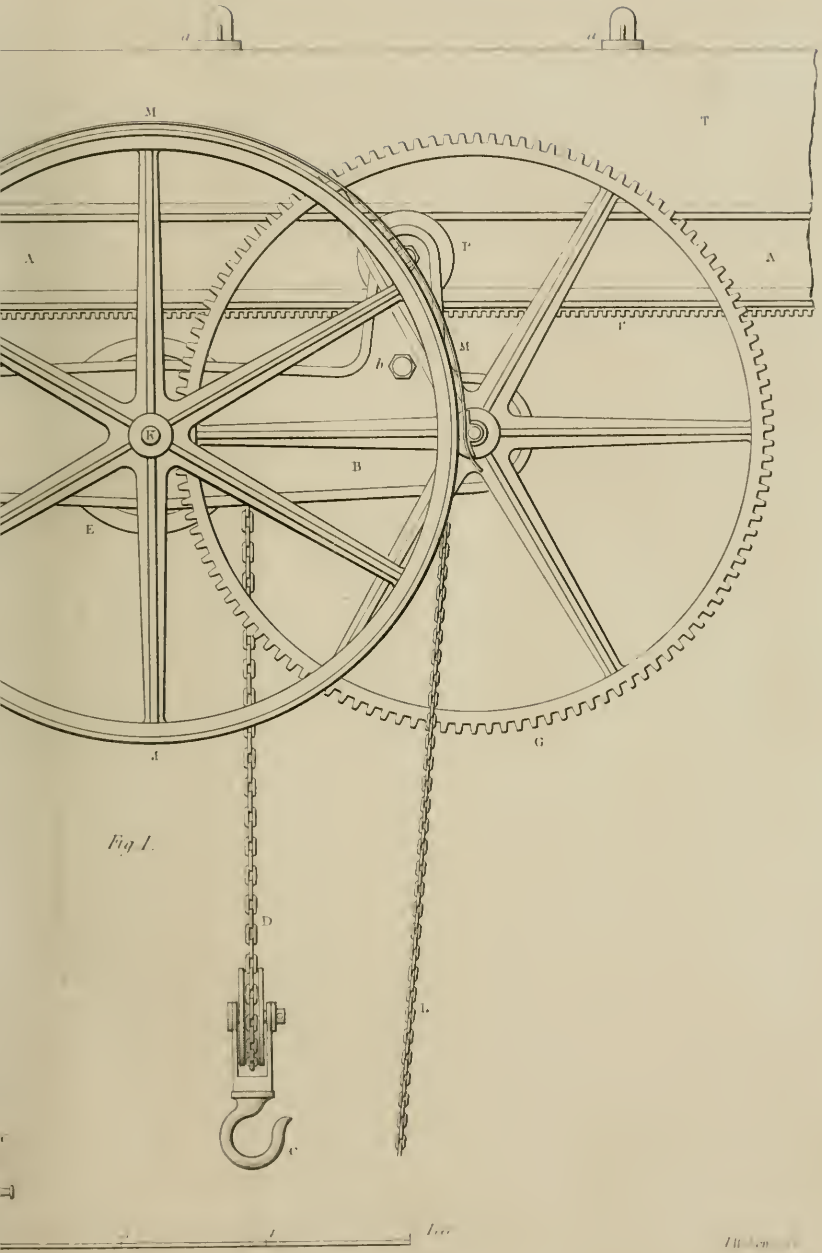

Fig. 1.

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Fig 3

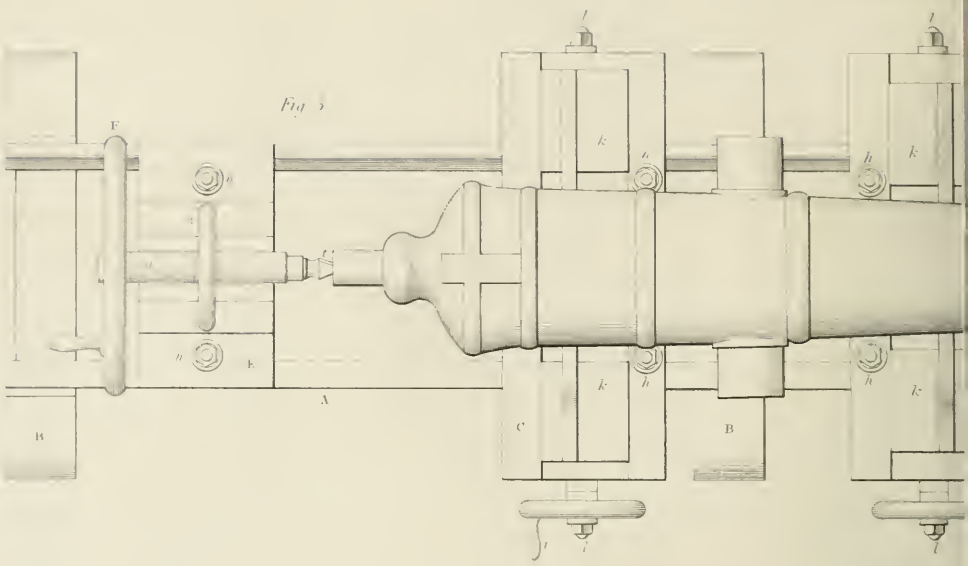

Fig 1

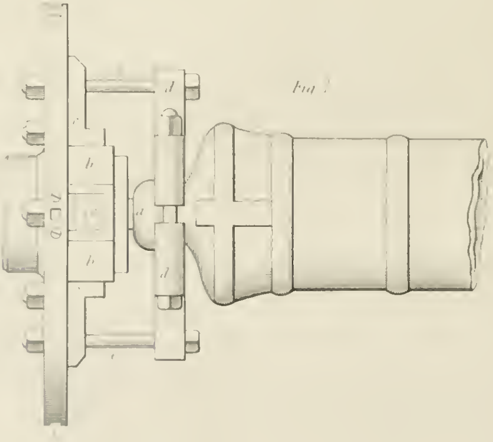

Fig 2

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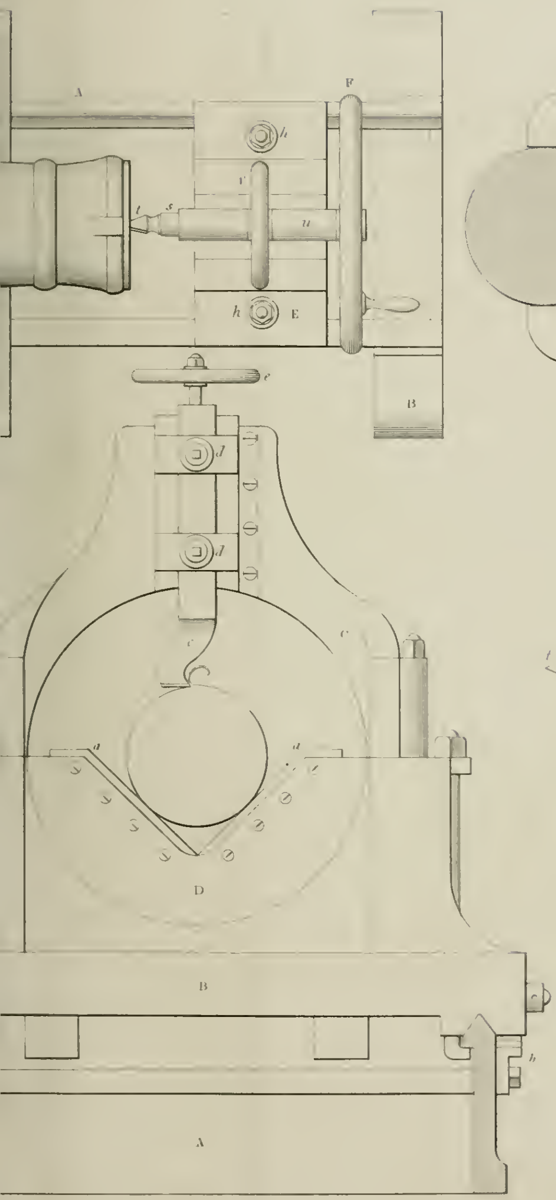

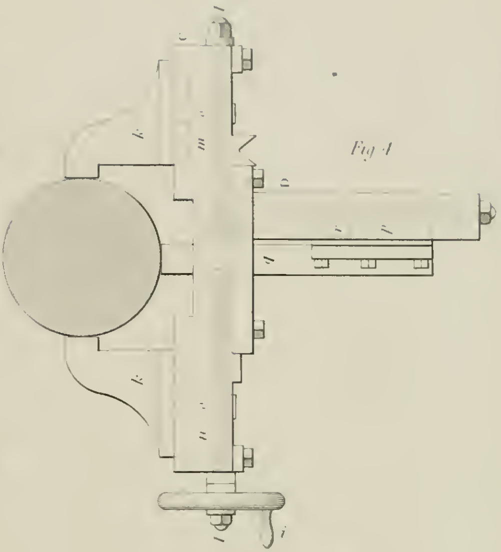

Fig 4

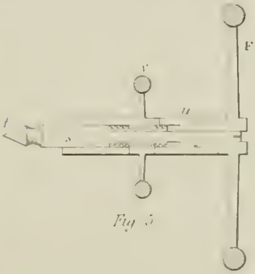

Fig 5

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C.W. Lowry

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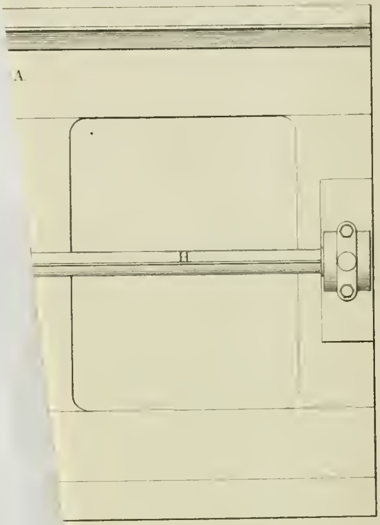

J W Lowry sc

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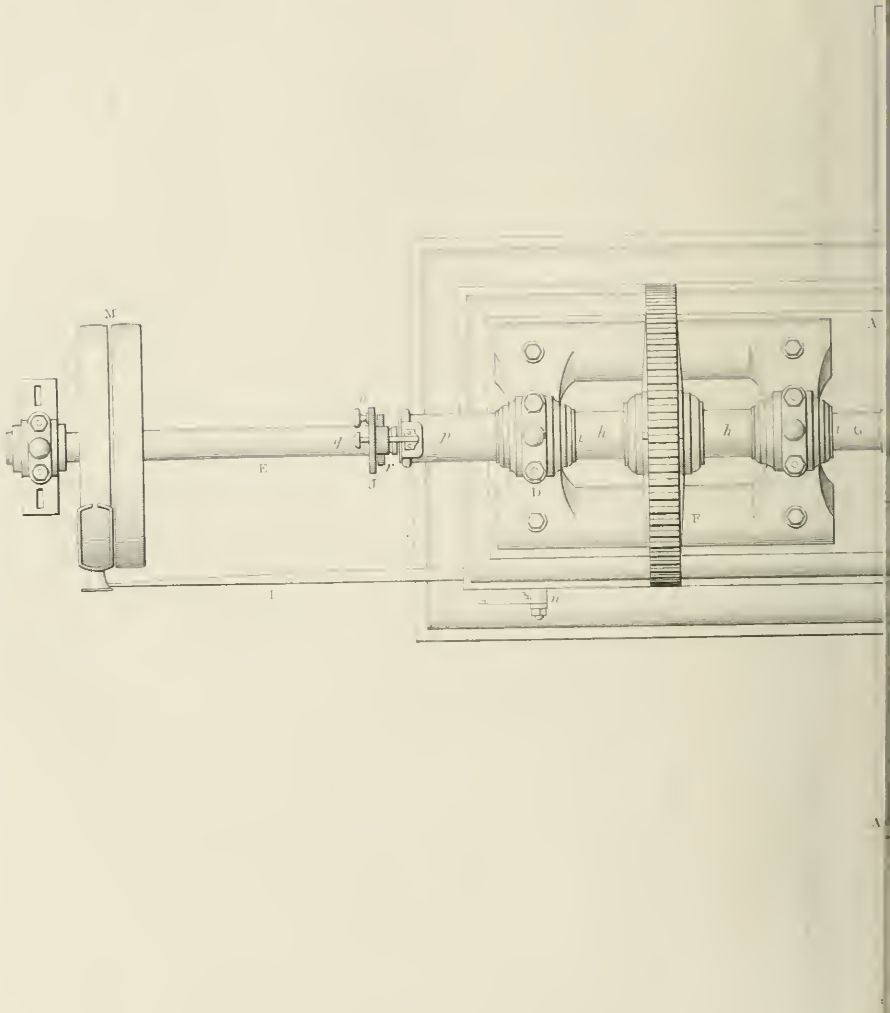
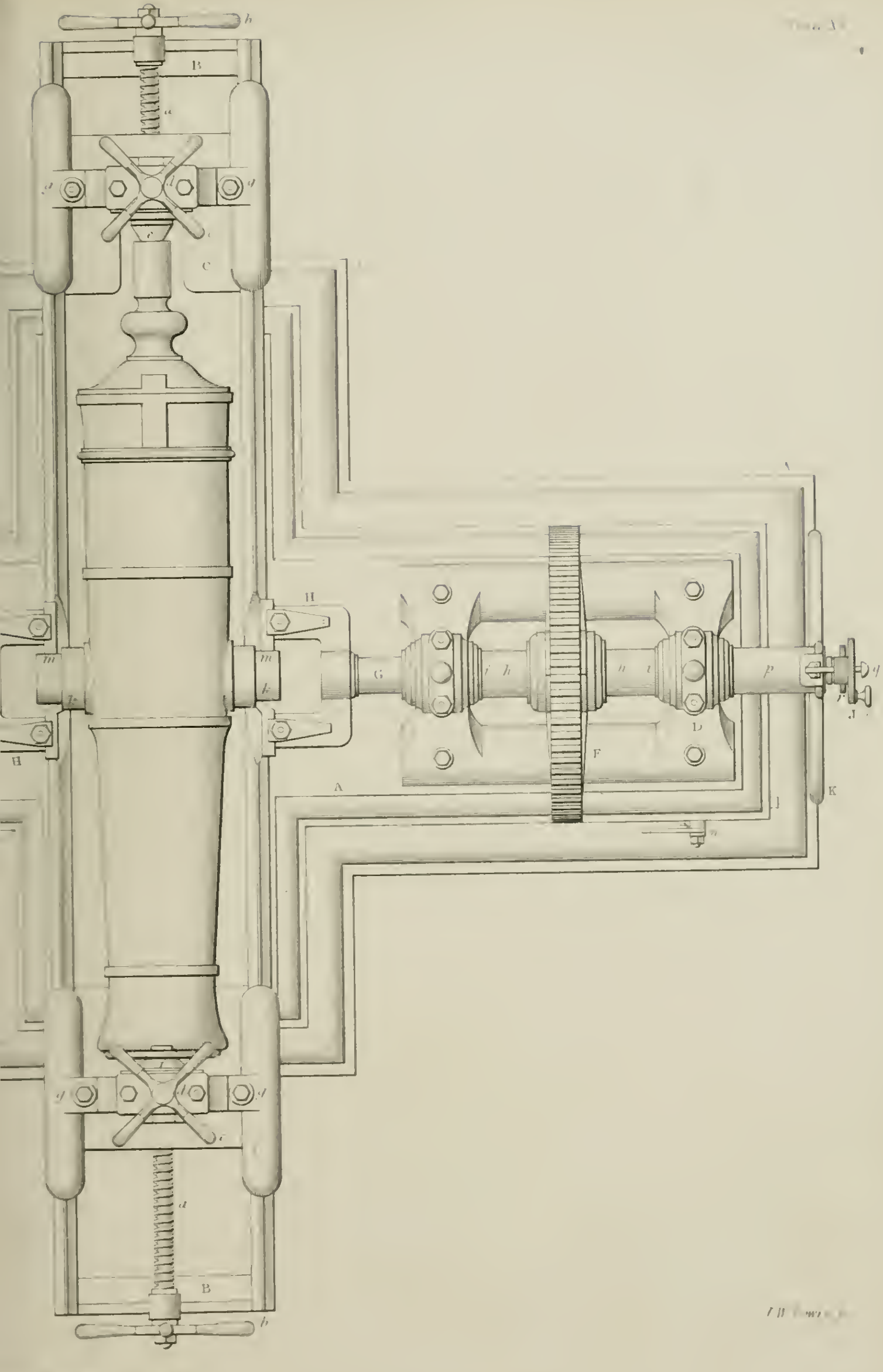
TRUNNIONING MACHINE





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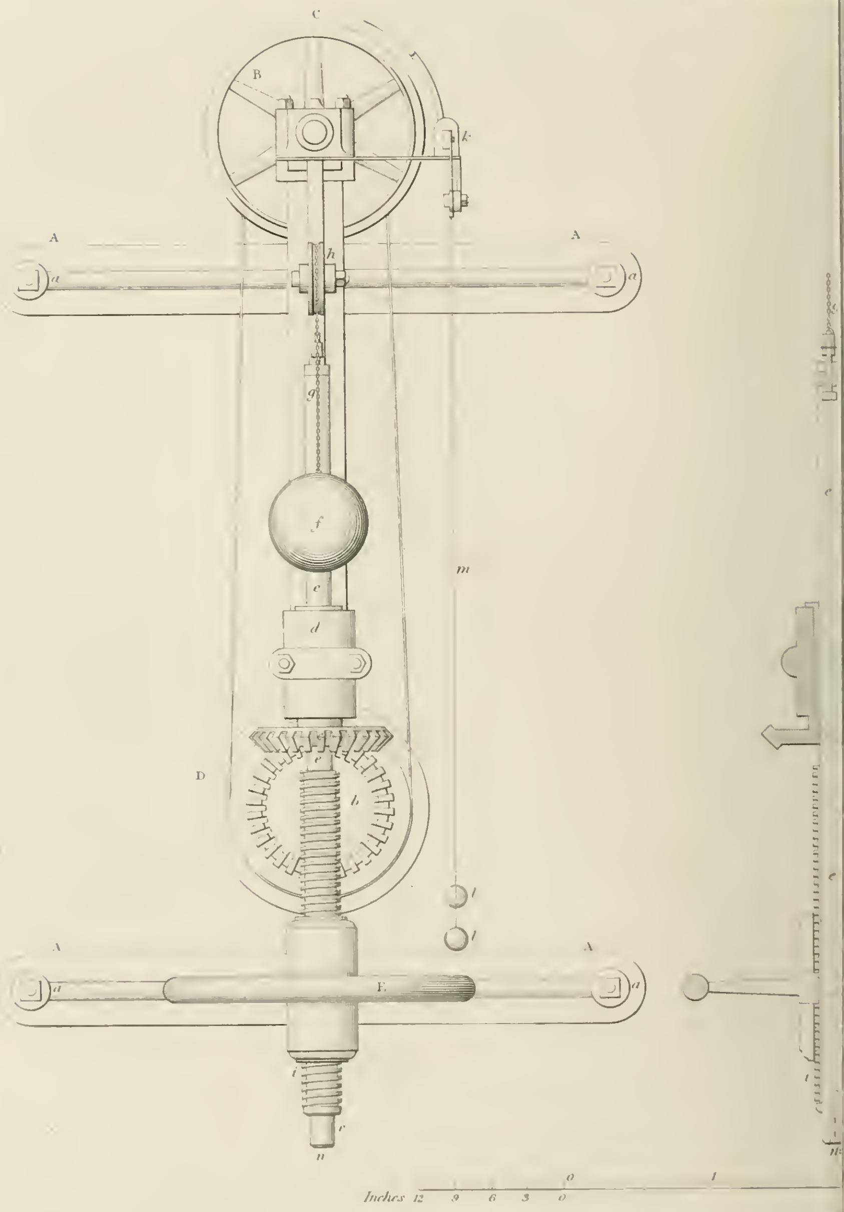

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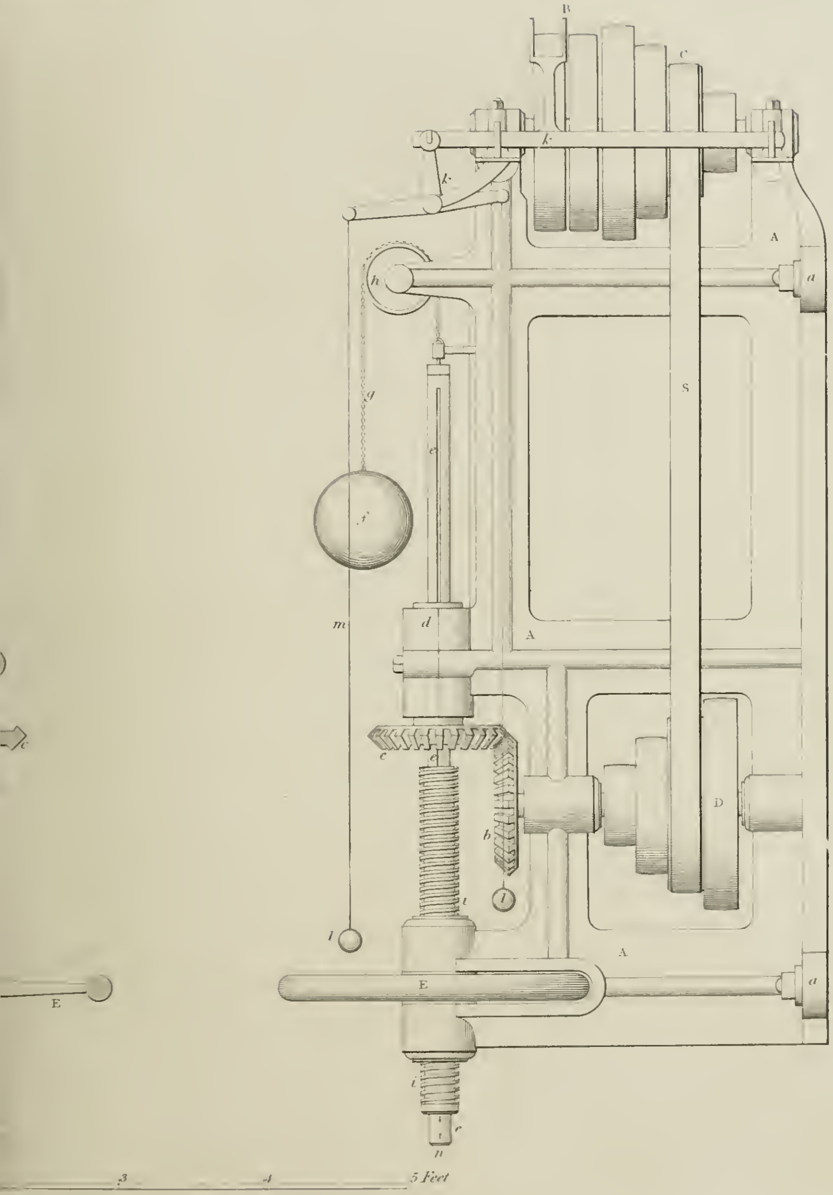


ue 59 High Holborn, 1845.

J W Lowry fc

BOUCHING FRAME.

Fig. 1

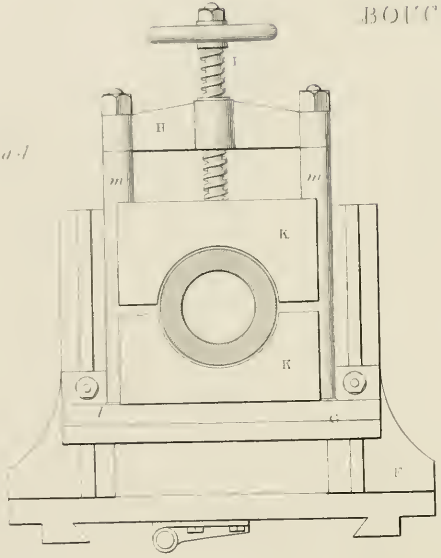


Fig. 3

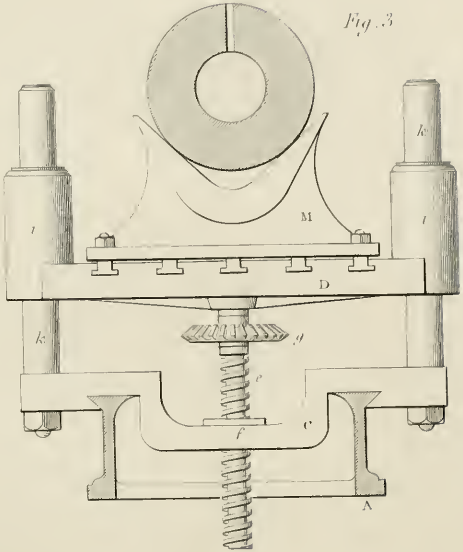
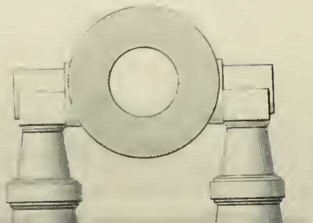


Fig. 2



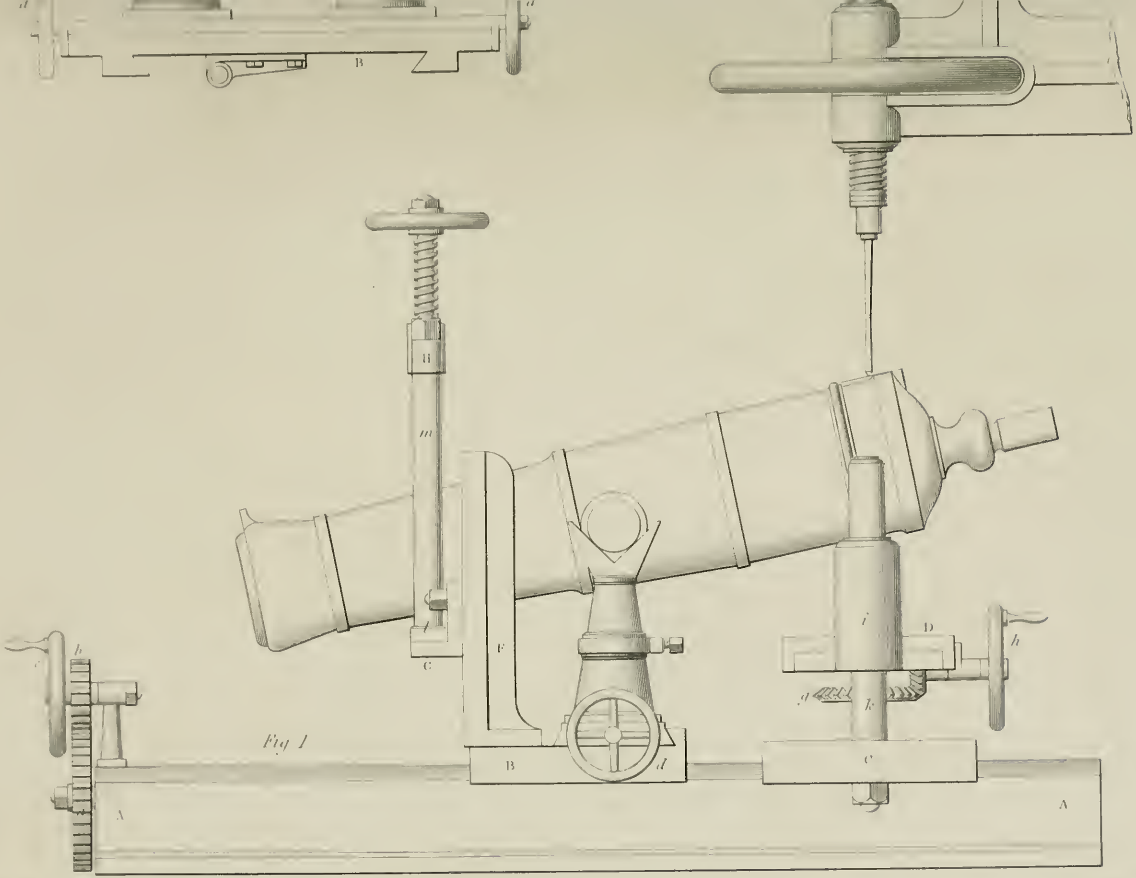


Fig 1

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VII.—*Notes on a Coffer-Dam constructed in Her Majesty's Dockyard, Devonport.*

This coffer-dam has been constructed for the purpose of building a sea wall and an entrance into a future ship basin. The dotted lines (A, A, A, figs. 1 and 2, Plate XVIII.) show the general outline of the proposed basin, with its entrance, and two docks out of the basin. The entrance to the basin will be 70 feet wide, and have a depth of water of 27 feet at high-water neap tides. The plan of the dam, as first constructed, is shown at B, B, B, figs. 1, Plates XVIII. and XIX. A part of the shoring is shown as first designed in fig. 1, Plate XIX., and by the section, fig. 3, Plate XVIII. The abutment of the shoring was against sheet piling filled in at the back, where the ground made such means available, as at C, C, C; and at the entrance to the boat basin, against an arch of old ship timber, as at D, D. A dam was made across the entrance to the boat basin (E), to cut off the water in that direction, and a temporary entrance to the basin was opened at F, in order to preserve the use of the basin and dock therein as long as possible.

An inspection of the plan in Plate XVIII., and of the section, fig. 1, Plate XIX., will give a general idea of the system of shoring and bracing proposed for the coffer-dam. It would not be profitable to enter into a detailed description of it, as it was soon found necessary to depart from it, and it was not put to the proof.

The coffer-dam was constructed with three rows of piles (fig. 2, Plate XVIII.), the mud dredged from between each pair, and clay filled in. In the section the clay is shown between the two outer rows of piles, filled in up to half-way between high and low-water lines; between the two inner rows, up to high-water line.

When the clay was filled in between the two inner rows, up to about 4 feet above low-water line, it burst in the inner row of piles above the surface of the mud, at G, G, which was about the deepest part of the dam; some of the piles there being 67 feet long, and driven 27 feet into the mud. The fact is, that from the waling at low-water line to the surface of the mud, a distance of more than 20 feet, the piles being unsupported, the pressure of the clay burst in the piles. Clay has a tendency to swell and spread out. Mixing up gravel, stone chippings, &c., with it, will counteract this in a great measure, but it is doubtful whether it would have been sufficient in this instance. A second row of piles was driven close behind the fractured ones at G, G, and it was determined not to raise the clay higher than low-water level or thereabouts, and to trust to caulking for making the dam water-tight above that. This check induced a little consideration. The ground at C, C, is made ground: the sea wall at H, H, H, was built by diving bell, on piles which were known to be worm-eaten at the head. Some holes dug behind the sea wall (H, H), showed that the tide had free ingress and egress. It was necessary to secure the flank of the dam at H, and it was judged advisable to contract the size of the dam by constructing an interior portion (I, I, I). To secure the flank (H), the sea wall was cut through by the use of a diving bell, and the dam (K, K, K) was constructed, the mean section of which is shown at fig. 2, Plate XIX. Rock was found at low-water level at that end of it next the storehouse. A trench was excavated, two rows of piles driven to low-water line, the earth dredged from between them, and the space filled in with clay, which was tapered up from the heads of the piles to high-water level, and the earth filled in and rammed.

The inner dam (I, I, I) being driven, and the shoring fixed, advantage was taken of low tide to shut out the water by the culvert. When the tide had risen rather more than half, the shoring in one part was heard to crack, and the water was therefore suddenly let in by the culvert. It must be observed that the portion I, I, I, did not form part of the original plan, and because of its figure, the shoring was irregular, and controlled in some manner by existing work. There was, therefore, a weak point in it which had escaped notice. The above are reasons also why the shoring of this inner coffer-dam is not shown in the drawing nor described. When the defect in the shoring was corrected, the water shut out again, and the pumps set to work, and when the tide had risen, the inner row of piles at L, L, burst in above the surface of the mud. As neither of the outer rows of piles were at all disturbed, it is presumed that by letting in the water suddenly through the culvert, the mud at the foot of the piles was washed away, and the same state of circumstances, as at G, G, then produced the same effects. There is the more reason to suppose this, as the mud was afterwards found heaped up in the opposite corner of the dam.

The fractured piles were drawn, and others driven in their place. Also, to prevent a recurrence of similar accidents, the inmost rows of piles, (M, M, M), near the line of the foot of the masonry in front and at back, were driven; not as a water-tight dam, but to support rubble which was thrown in between these rows and the main dam, up to the level of low water nearly. Fig. 2, Plate XVIII., is a section showing this arrangement: N, N, N, are the rows of piles last driven, and thus the inner space of the dam at low water was contracted to that space actually required for the masonry.

As the water was lowered by the pumps and the mud was excavated, waling and shores were introduced at every 5 feet. A set of waling and shores was kept in readiness, and the shores being short, and not requiring bracing, trussing, &c., they were easily and quickly inserted. Operations then went on successfully, the mud was excavated, the rocks (slate) levelled, and the masonry built in, the first stone being set at 55 feet below high-water average spring tides, until it had risen to a level which made it advisable to bring up that part of the invert for the caisson included in the dam at O. The excavation at that part was commenced; but when it had reached the rock in one part, and preparations were being made for beginning the masonry there, a strong leak occurred about the spot P. Whence it arose was never clearly determined. Probably some of the piles at the angle were not well down, for the whole ground was very foul with old mooring chains, anchor stocks, pieces of oak plank, &c. However, it could not be conquered, and therefore it was decided to include the defective part by extending the dam as shown by the part shaded dark, which would take in about 15 feet beyond the centre of the invert for the caisson. This was accordingly done. The rows of piles (Q Q) were drawn, P being left as a kind of intermediate abutment for the shoring in this new compartment of the coffer-dam. The water was pumped out, the excavation made, and waling and shores inserted at every 5 feet of depth. Thus the rock was again reached, and preparations made for commencing the masonry; but again did the water break in at the side (R), near the bottom. The outer row of piles remained undisturbed.

The section, fig. 3, Plate XIX., will show the cause of this last failure. The line of masonry, in plan, will be parallel to the line of piles (R), and at about 6 feet from it. A bank of mud and slate rock, 5 feet wide, was left at the foot of the piles, and too much dependence was placed on this bank for supporting the lower 5 feet of the piles. There should have been another set of shores there. Probably the very driving of the piles into the ground and rock had destroyed its consistency, so that it afforded little support to them.

The piles were every where driven to the rock, which is slate, and rather soft at the surface; but wherever opportunity was offered by excavation, of seeing the effect of the pile shoes on the rock, it was found that it was shivered up into small fragments.

The remedy proposed for this last failure, is to drive a row of piles parallel to the fractured ones (R), at about 5 feet from them, and to fill in the intermediate space with rubble; also, to support the foot of this new row of piles with rubble, which will afterwards have to be excavated again, and replaced by shores as the water is lowered. This operation is now in hand.

A few profitable lessons may be learned from the above failures. The first was caused by the simple pressure of clay acting against a long length of the piles, which, being below low water, was unsupported by shores or otherwise. The water was level inside and outside the dam. It might be possible to introduce shoring below low water by means of the diving dress, &c., but probably it would be impossible to do so, at such a depth as in the present instance, in a manner on which to place any dependence; especially where the shoring is not simple and direct, but requires to be braced, trussed, and carried some distance to an abutment. The mode of getting over the difficulty in this instance was probably the best that could have been adopted for the locality. The piles from low water down to the surface of the mud, the surface or softer part of which was of course displaced by the rubble thrown in, became supported by a substantial bank or wall of rubble, 9 or more feet wide. The mud itself below that became the support, and it was found that this, where undisturbed, was very solid. The rubble used was procured from the Breakwater quarries, and was admirably suitable for the purpose. It consisted of the small rubble and chippings of the quarries, which had a good deal of clay mixed with them. It had weight and consistency, and was without that tendency to swell and spread out which pure clay has. The arrangement also having reduced the interior space of the coffer-dam to a limited size, the shoring became very simple and easy of execution; an object to be particularly aimed at, especially where the dam has much depth, and where there is a possibility of any of the piles, below low water or below the surface of the mud, turning out

Fig. 5

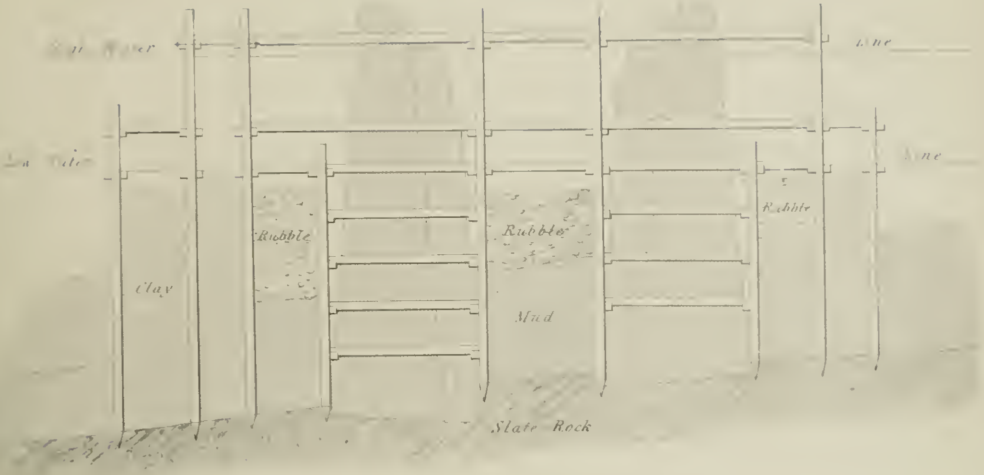
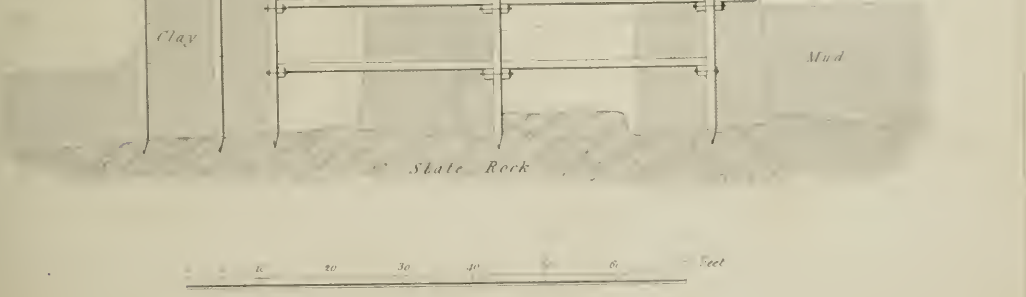


Fig.



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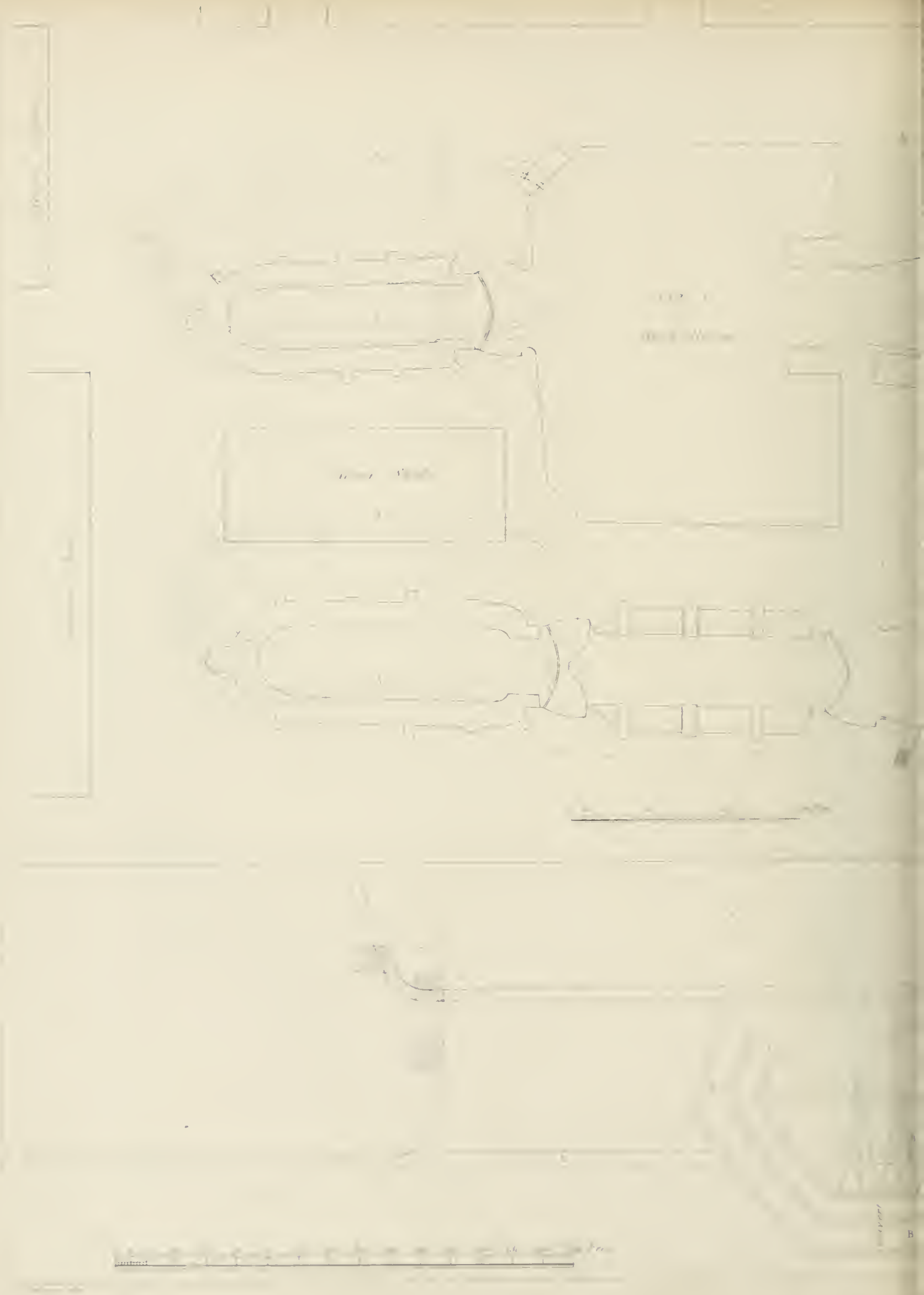

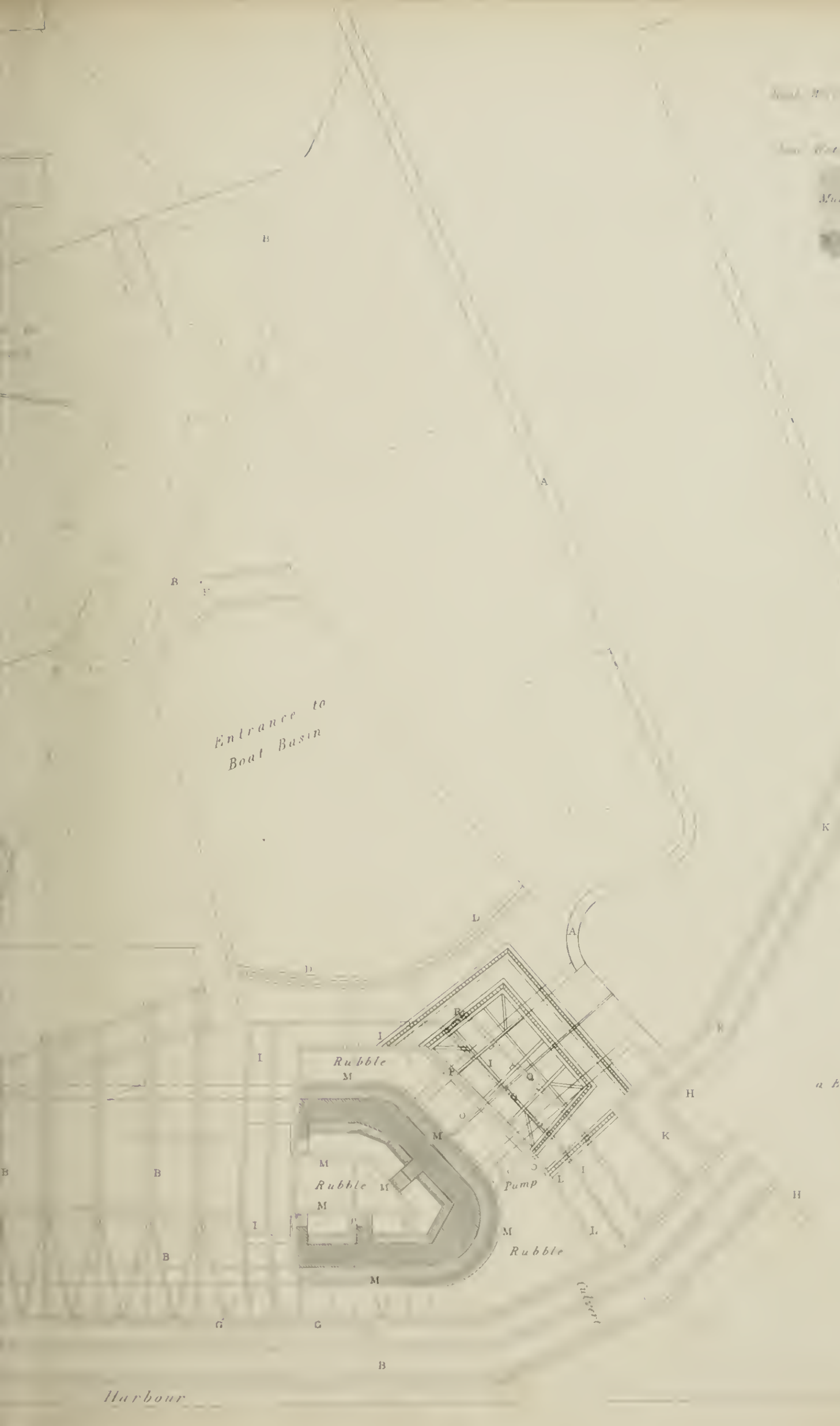

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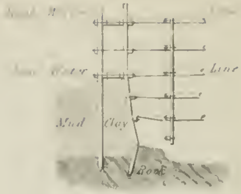
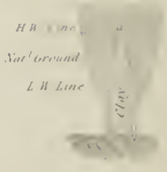


Fig



a Earth filled in & ramed

defective, or having been driven out of line. In this dam, many of the piles are 60 feet or more in length. The rise and fall of the tide at extraordinary spring tides is 18 feet. Supposing the upper waling affixed to the guide piles to be fixed 2 feet above high water, making 20 feet between the upper and lower walings, and supposing a pile 60 feet long to be driven as a sheeting pile, there will then be about 35 feet of the pile below the lower waling, or below low water, which might take a direction 2 or 3 feet out of line at the toe, without the circumstance being perceptible at top. If such a case should be discovered on pumping out the water and making the excavation, there is infinitely greater chance of patching up a defective part where the shoring is simple and in short lengths, than where it is complicated. Besides, any operations connected with or affecting the shoring, should be done at low water, the time of which is very limited.

The second failure probably arose from a culvert having been opened suddenly, which let in a large body of water with a fall, thereby removing the supporting mud from the front of the piles. The lesson to be learnt from this is obvious enough,—either to let in the water very gradually, or to let it fall on a platform of timber, or to lead it away through a shoot or trough to some part of the dam not likely to be injured; or, where there is choice, to place the culvert where it cannot do injury.

The third failure teaches us not to place confidence in banks, unless established on a broad basis; indeed, never to consider a dam secure when more security can be given to it, and, within reasonable limits, to multiply the shoring up to that point where it would begin to impede the ulterior purpose of the dam.

These notes will probably be continued on some future occasion.

Geo. H. Burgman,

March 26, 1845. Captain, Royal Engineers.

VIII.—*Description of James Nasmyth's Patent Steam Hammer.*

Before describing the steam hammer, it may be as well to make a few remarks on the general principle and construction of the ordinary forge hammers, with which we shall have to contrast it in respect to its action, power, and capabilities. For this purpose it will be best to refer to fig. 1, Plate XX., which will convey a general idea of the construction and arrangement of one of the most improved ordinary forge hammers, in which it will be seen, that in order to produce the requisite lifting and falling motion of the hammer (A), the original rectilineal motion of the piston rod of the steam engine has to pass through all the complex media, consisting of beam (B), connecting rod (C), crank (D), shaft (E), fly-wheel (F), belt (G), to the fly-wheel (H), from that to the cam shaft (I), and finally, through the sliding of the inclined backs of the cams under the tail (T) the hammer (A) is raised and let fall by a sort of jolting action, as each cam passes in succession under the tail (T). In this truly roundabout manner is the original straight up and down motion of the piston rod so far recovered and transferred to the hammer (A), only in a modified and very inconvenient manner after all, inasmuch as the hammer (A), resting on its rocking centres (K), does not permit its face to strike the work in a manner parallel to the anvil, except at one particular height, which, in many cases, is found to be a source of great inconvenience; and as there are no means provided in such hammers for modifying the force of the blow, we are obliged to be content to take what it deals out in its own brute-force style; and with this disadvantage, in addition, that on account of the impossibility to vary the height of the fall, except within very short limits, in the case of hammering a large or thick object, the clear space between the anvil face and hammer face is so nearly filled up by the work on the anvil (as seen in fig. 1), that little or no clear space is left for fall; and consequently, at the very time we want to have most powerful blows, we then get the least powerful, and the reverse; add to which the great space occupied by the entire apparatus of engine, fly-wheels, and hammer, and the enormous loss of power incurred in the transmission and twisting about of the original power before it reaches the final object.

Having said thus much on the subject of the ordinary forge hammer, we shall now proceed to describe the steam hammer, which simply consists of an inverted cylinder (A, fig. 2), whose piston rod comes out at the bottom of the cylinder, and is attached at once to a block (B), or mass of iron, sliding vertically between two upright guide standards (C, C). This block answers as the hammer, and is placed in a vertical line right over the anvil block (D); so that whatever height the hammer face is raised up above that of the anvil block, the two faces are parallel at all heights. The mode of action of this apparatus simply consists in the alternate admission of high-pressure steam under the piston (H, fig. 3, Plate XXI.), which raises up the piston, and with it the piston rod and hammer block (B). As soon as it has attained the required height, the cam (E, fig. 2) comes in contact with the valve lever (F), which it moves in such a position as to cause the valve (V) to permit the steam under the piston to escape, which is instantly followed by the fall of the hammer block (B), with such force as is due to its weight, and the space through which it falls, which can be increased or diminished at pleasure, by shifting the position of the valve lever (F), so that the cam (E) shall come in contact with it when the hammer is at a greater or less height from the anvil block, as the case may require. As there is little or no friction in the moving parts of this simple arrangement, and as there is no loss of power in the means employed (namely, the elasticity of the steam), in producing the lifting action of the block (B), and little or no destructive action in the manner in which the steam exerts its power, the whole apparatus is at once simple, compact, convenient, and highly manageable; so much so, that all varieties of force of blow can be given out from the same machine, from that powerful enough to cause the hammer face to sink into a piece of hot iron, as if it were so much clay, or at another time to drive a nail into a piece of soft wood with all the neatness and care of a joiner with his hand hammer.

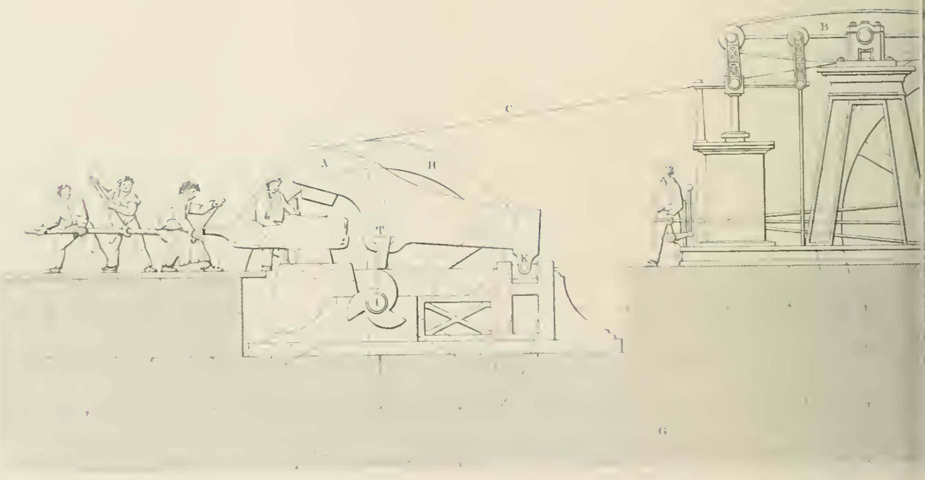
As the space on each side of the anvil is quite clear, and the two side standards (S, S) wide apart, every facility and accommodation is afforded for the execution of the most awkward-shaped work; and as every ounce of weight in the hammer block, even including the weight of the piston and piston rod, is converted into available momentum, and made to act simultaneously in giving out the blow, the blows so given out by this hammer are truly effective; and when it is desired to modify the blow on an instant, to suit any intentional or accidental occasion, the steam is permitted, by drawing back a trigger handle (T), to re-enter below the piston before it has reached its lowest point of fall. The result of this is, that it falls *on* high-pressure steam, which forms the most perfect cushion, and arrests, without the slightest jerk or concussion, the most energetic descent of the hammer. On many occasions, this power of instantly arresting the blow proves of infinite value and convenience.

The closing of the steam or slide valve (V) was described to be caused by the cam (E) coming in contact with the valve lever (F), which the cam (E) moves up into the position as seen in fig. 4. This position enables the trigger catch to get its point in above the shoulder on the valve rod screw (Z), and hold it in that position until the hammer completes its fall. The instant this is the case, however, the latch (L) jerks down, and causes its end (X) to come in contact with the bar (P), which it presses back; and as this bar is in connection with the trigger catch, the fall of the latch causes the trigger to let go its hold of the valve rod at Z, which, by reason of a small steam cylinder and piston at N, is instantly moved so as to let the valve (V) come again into the steam admitting position, when the piston and hammer immediately rise as before, and the actions are all reversed, as already described. Thus the machine is rendered perfectly self-acting.

In conclusion, it may be well to describe a very important detail in this invention, namely, the manner and means by which the piston rod is attached to the hammer block. This is done through the medium of elastic or compressible substances; so that when the blow of the hammer takes place on the work, the concussion, which otherwise would soon be fatal to the piston rod and piston, is softened so entirely by means of this interposed compressible substance, (rough poplar wood answers best,) placed below and above the piston rod end at Y, that not the slightest injury has ever been known to arise from the most violent and unceasing action. The piston rod, having a solid end or knob, above and below which the wood packing is placed, and all kept fast by two cross-keys (O, O), the whole is rendered at once simple and substantial, as well as easy of access when it is desired to get at these parts.

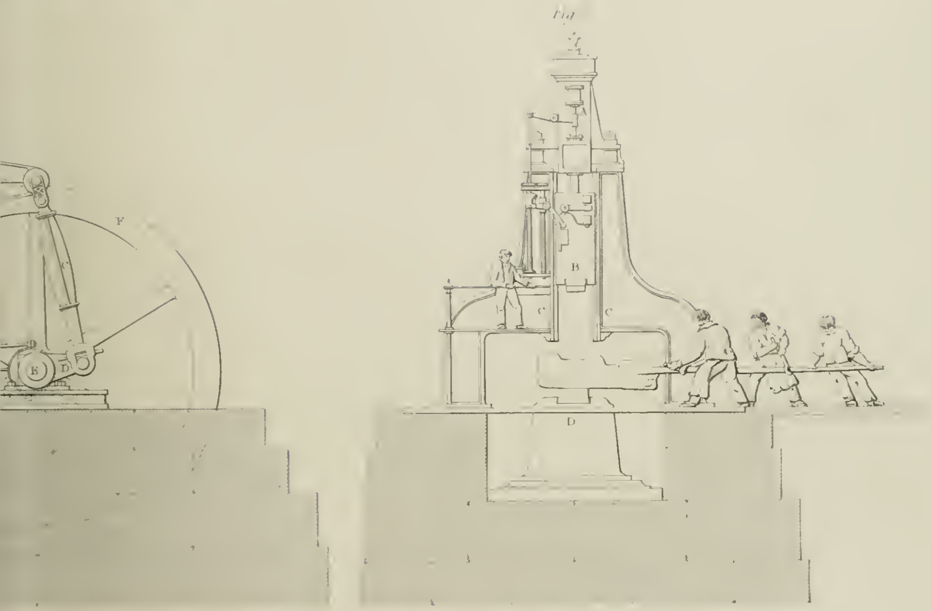
It will be observed, that the top of the cylinder is made steam-tight. The object of this is not only to exclude the cold air, but also to enable the

J. NASMYTH'S



[illegible] by J. Nasmyth's Patent Steam Hammer

TEAM HAMMER.



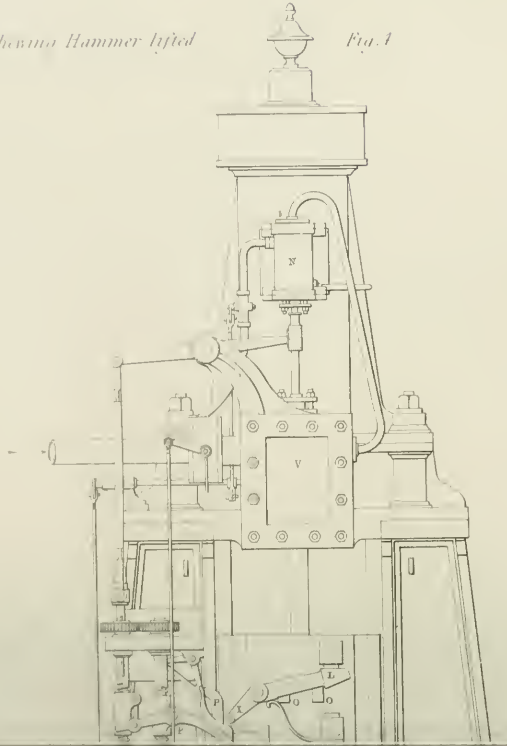
mpared with a Forge Hammer of equal power on the ordinary construction

J. NASMYTH'S

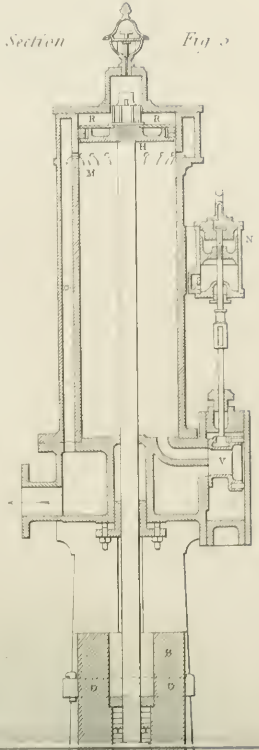
STEAM HAMMER

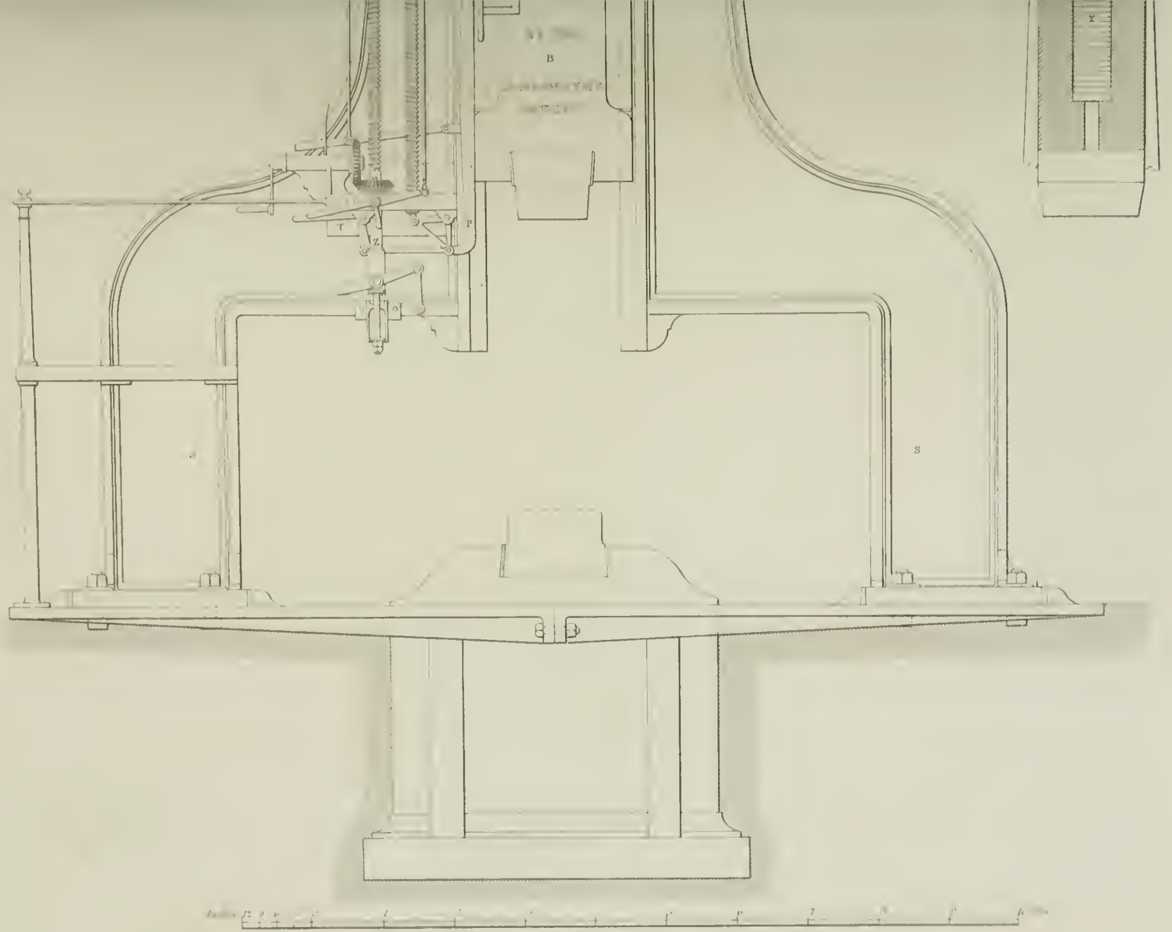
WEIGHT 2½ TONS

Elevation shewing Hammer lifted   Fig. 1



Section   Fig. 2





J. W. Lowry sc.

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stroke, when at its height, to be limited, and all risk of striking the cylinder top prevented; for as soon as the piston passes the row of holes in the cylinder at M, fig. 3, the piston confines the steam, or air, in the upper chamber (R, R), which finally arrests, by its accumulating elasticity, the upward motion of the piston, and adds that elasticity to the downward action of the piston at its next fall, which greatly enhances the effect of these highest blows.

JAMES NASMYTH.

IX.—*Description of James Nasmyth's Patent Steam Pile-Driving Machine.*

Before proceeding to describe this invention, it may perhaps be as well to make a few preliminary remarks, as tending to illustrate the subject, by explaining the chief difference in respect to the principle of action which distinguishes the old from this new system of pile-driving.

Although the mechanical force expressed by 4 ℔s. travelling with a velocity of 4000 feet per second, is *theoretically* equivalent to that of 4000 ℔s. travelling at the rate of 4 feet per second, yet in practice we shall find that the result of the blow given by these theoretically equal forces to any opposing body will present very different effects.

Let us consider what would be the result of each, were we to endeavour to drive a pile into the ground with such equivalent forces.

We should find that the result of a blow given to the head of a pile by a body weighing 4 ℔s., moving at a velocity of 4000 feet per second, would be this,—that in place of driving the pile into the ground, it would shiver it from head to foot into splinters, while it did not in any perceptible degree drive the pile: on the other hand, a blow to the same object by a mass weighing 4000 ℔s., moving at the rate of 4 feet per second, would, while it did not in the slightest degree injure the head of the pile, be found to drive it some 6 or 8 inches into the earth at each successive blow.

The question naturally presents itself, what is the reason of such vastly different effects, arising from forces which are said to be theoretically equal? the answer to which will be found in this,—that when we desire to communicate *motion* from one body to another in a state of rest, unless we give sufficient *time* for the transmission of the force of the blow throughout the entire mass of the body struck, we shall only produce destructive instead of impulsive action: the body struck will not be moved from its place, but rent and shivered into splinters or fragments, according to the nature of the material. In the other case, namely, the greater mass travelling with the less velocity, (viz., the 4000 ℔s. at the rate of 4 feet per second,) sufficient *time* is given (by reason of its comparative small velocity) for the communication of the impulse throughout the entire mass, which is in consequence impelled in the direction of the blow with corresponding and satisfactory results. A pile so struck will be rapidly driven into the ground without receiving the slightest injury from the force employed, simply because in this case we employ the requisite amount of force in a proper condition for the performance of the required duty. From these remarks, we may conclude that the proper condition for mechanical force, for the purpose of driving piles, should be the very reverse of that of the blow of a cannon ball, in which, although there is embodied as it were a vast amount of momentum, yet it is not momentum or force in a condition at all suited to impel a mass of materials, such as a pile: as before said, the exertion of such quality of force would not drive the pile in the least perceptible degree, but would shatter it into splinters. For the purpose of pile-driving, we ought to employ our force in a condition quite the reverse of that of a cannon ball; namely, instead of a *small mass* of iron travelling at a high velocity, we ought to employ a large mass or block of iron falling on the head of the pile with a moderate velocity, and make up for a want of velocity by the frequency of the blows. These desirable conditions will be found to be presented in high perfection by the steam pile-driving machine, which we shall now proceed to describe.

The chief features of novelty in this invention consist, in the first place, in the *direct* manner in which the elastic force of steam of high pressure is caused to lift a mass or block of iron, by the often-repeated fall of which on the head of the pile it is driven into the ground; and secondly, in the peculiar manner in which the greater part of the weight of the apparatus is rendered available or made to assist in forcing the pile down. This is effected by its being set on the head of the pile, in which position it materially increases the effect of the blows by the dead weight of the apparatus, which includes the weight of the hammer or block, the whole going down along with the pile as it is incessantly knocked down into the ground. By the combined action of these two agencies, namely, the blows from the block of iron (which forms as it were the hammer), together with the dead weight of the whole apparatus, results, as to rapidity of pile-driving, are in this way obtained, such as form a strong contrast with the old system.

Plate XXII. By reference to the engraving, we shall be enabled more particularly to describe the general arrangement and action of the details of this novel machine.

Fig. 1 represents a general view of the entire apparatus, as erected at Devonport, and employed in the construction of the coffer-dams for the great Steam Dock about to be constructed by the Admiralty.

The apparatus consists of a cylinder (A), whose piston rod comes out at the bottom, and is attached to a block of cast iron (B), weighing 50 cwt., which acts as the hammer or ram of the pile-driver: this hammer or block of iron is guided in its rising and falling motion by sliding inside a wrought iron case (C), at the lower end of which is a suitable socket, so as to enable the entire apparatus (A, B, C) to rest on or be supported by the shoulders of the head of the pile in such a manner, that while the head of the pile is left exposed to the blows of the hammer face (B), the entire weight of A, B, C, shall be constantly tending to press the pile (D) into the ground; the chain (E) being for that purpose left quite slack.

Steam of suitable pressure is then introduced below the piston in the cylinder (A), by means of the folding or flexible steam pipes (*a*, *a*, *a*), which serve to convey the steam from the boiler (F), whatever be the position of A, B, C, with respect to it. The instant the steam is admitted, the hammer block (B) is raised up 3 feet, on arriving at which height it cuts off the further supply of steam, and as instantly lets that which had served to raise the piston and attached hammer escape: this action is instantly followed by the fall of the hammer block (B) on the head of the pile, which, from the effect of so energetic a blow, is instantly driven into the ground to such extent as the nature of the soil admits: the sinking down of the pile is also followed by a corresponding sinking or following down of the entire apparatus (A, B, C), which action accompanies each successive blow; and as the steam is re-admitted under the piston on the instant of each blow being given, the action proceeds with a degree of energy and rapidity, such as peculiarly distinguishes the action of this apparatus. The ordinary working rate is eighty blows a minute; the result of which energetic action is that the pile is driven to the required depth in a few minutes. This being accomplished, the winding gear (G), which receives its motion from a small cylinder placed under the boiler and worked by the spare steam, is started, and the entire apparatus moved onward to the place where the next pile is to be driven; and as the next pile had been elevated by the capstan rope, and slung all ready during the driving of the last pile, no time is in that respect lost. The apparatus (A, B, C) is wound up by the winding gear (G), and placed on the head of the next pile to be driven. The chain (E) is again left slack, so as to leave the entire weight of A, B, C, (equal to 5½ tons,) resting on the shoulders of the pile. The steam is then admitted again under the piston (A), and the hammering action re-commences with all due energy, and continues working away at the head of the pile, following it down as it sinks into the ground, never ceasing to give out its sturdy blows till it is driven to the required depth. As the apparatus is represented in fig. 1, it is mounted on a wooden platform, and rolls along two rails (K, K), from pile to pile. The platform has also an advancing motion in the direction O, P, so that a double row of piles may be driven at any interval less than 10 feet apart in the direction of O, P, or close together, if so required. There are no limits, save the length of the gangway, in the other direction. The entire machine is, in fact, at once a self-acting pile-driving machine and locomotive engine.

It may be as well to observe that the socket at the bottom of the guide case (C) has a mouth-piece (W), so constructed as to grasp the sides of the pile, and causing it in effect to be a part and parcel of the entire machine: during the driving, it is in that simple manner kept from twisting or swerving from the exact vertical position it had at the commencement, as it is, for the time being, a part of the entire apparatus. The apparatus (A, B, C) is securely guided in its descent by the grasping arms which lay hold of the guide rails on the face of the upright guides, down which it slides as the pile sinks into the ground.

The entire apparatus is made so as to be removeable into a barge, and so rendered capable of driving piles out in the river or sea, as the case may require.

Reference to figs. 2 and 3 will enable me to describe the action of the details of the part of the apparatus referred to in fig. 1, as A, B, C; the same letters in this case being applied to the same parts.

In fig. 2, it will be observed, that according to the position of the parts of the apparatus, a blow has just been struck; and according to the then position of the valve, the steam is again entering under the piston: this is instantly followed by the lifting of the hammer block by the piston and rod, to which it is attached. As soon as it reaches the height indicated in fig. 3, the upper edge of the hammer comes in contact with the steam valve lever (X), which it raises up, and at the same instant not only shuts off all further supply of steam to the under side of the piston, but also permits that which had entered to escape: this being the case, the hammer descends with all due energy on the head of the pile, and knocks it so far into the ground. The concussion which accompanies this blow causes the latch (Z) to jerk down from the position seen in fig. 3, to that seen in fig. 2: this jerk down of the long end of the latch (Z) causes the short end to come in contact with the tail of the trigger (T), which is thereby drawn back out from under the shoulder on the valve rod (R); this permits the steam, which presses constantly on the small piston on the upper end of the valve rod at R, to force the valve instantly into the steam admitting position, as seen in fig. 2: this of course is instantly followed by the rise of the piston and the attached hammer, which, on coming again in contact with the valve lever (X), lifts it and the valve rod (R) up into the position seen in fig. 3, where the retaining trigger gets again in under the shoulder on the valve rod, and keeps the valve in the shut-off steam position until the next blow liberates it, as before described: thus the hammering action of the machine is rendered quite self-acting.

It may be well also to describe how the upward motion of the piston is arrested at the right point, as otherwise it might, when working with undue energy, knock out the top of the cylinder. This is accomplished by having the top or upper part of the cylinder quite air-tight, so that as soon as the piston passes the holes at S, (which are all round the cylinder at that part,) the air or steam which is shut up in the chamber (V, V) acts as an air cushion or buffer of the most perfect character, and not only arrests any undue rise of the piston, but transforms the so resisted upward force into additional *downward* action, so as to add very importantly to the energy of the blows, as this action takes place at every stroke of the hammer.

In fig. 2, the pile is exhibited as if knocked to a small extent out of the socket by the effect of the blow. In the actual working of the machine, so rapid is the following down of the entire apparatus the instant after the blow

Fig. 1

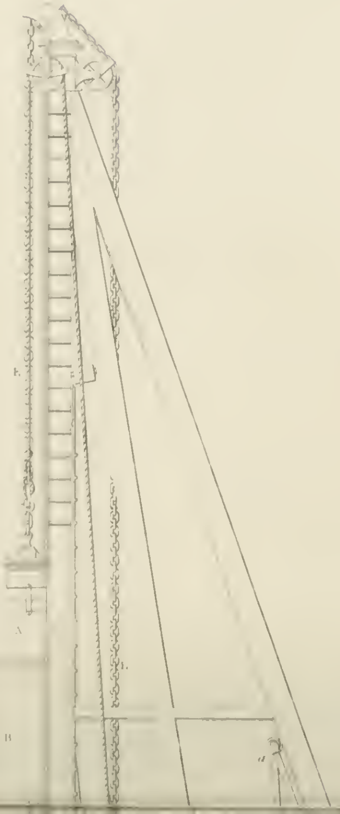


Fig. 2
Section
shewing Hammer lowered

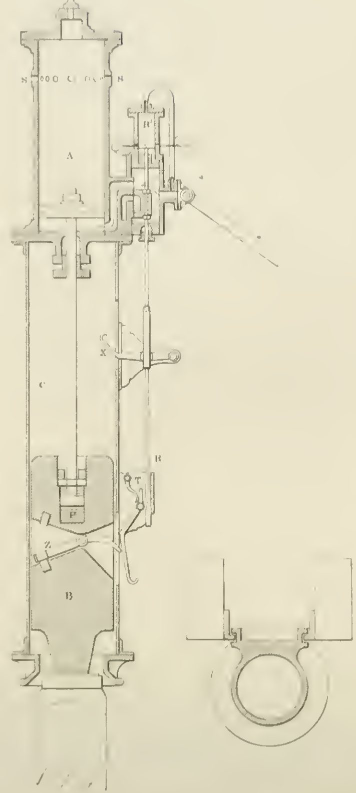
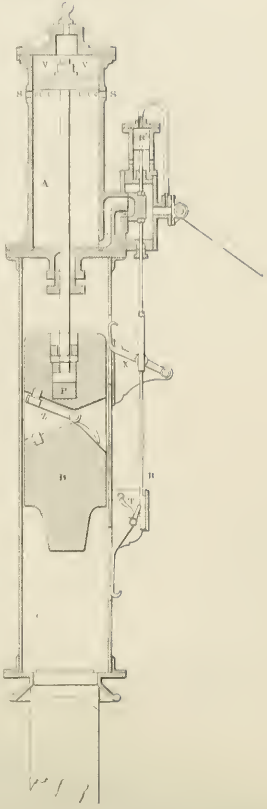
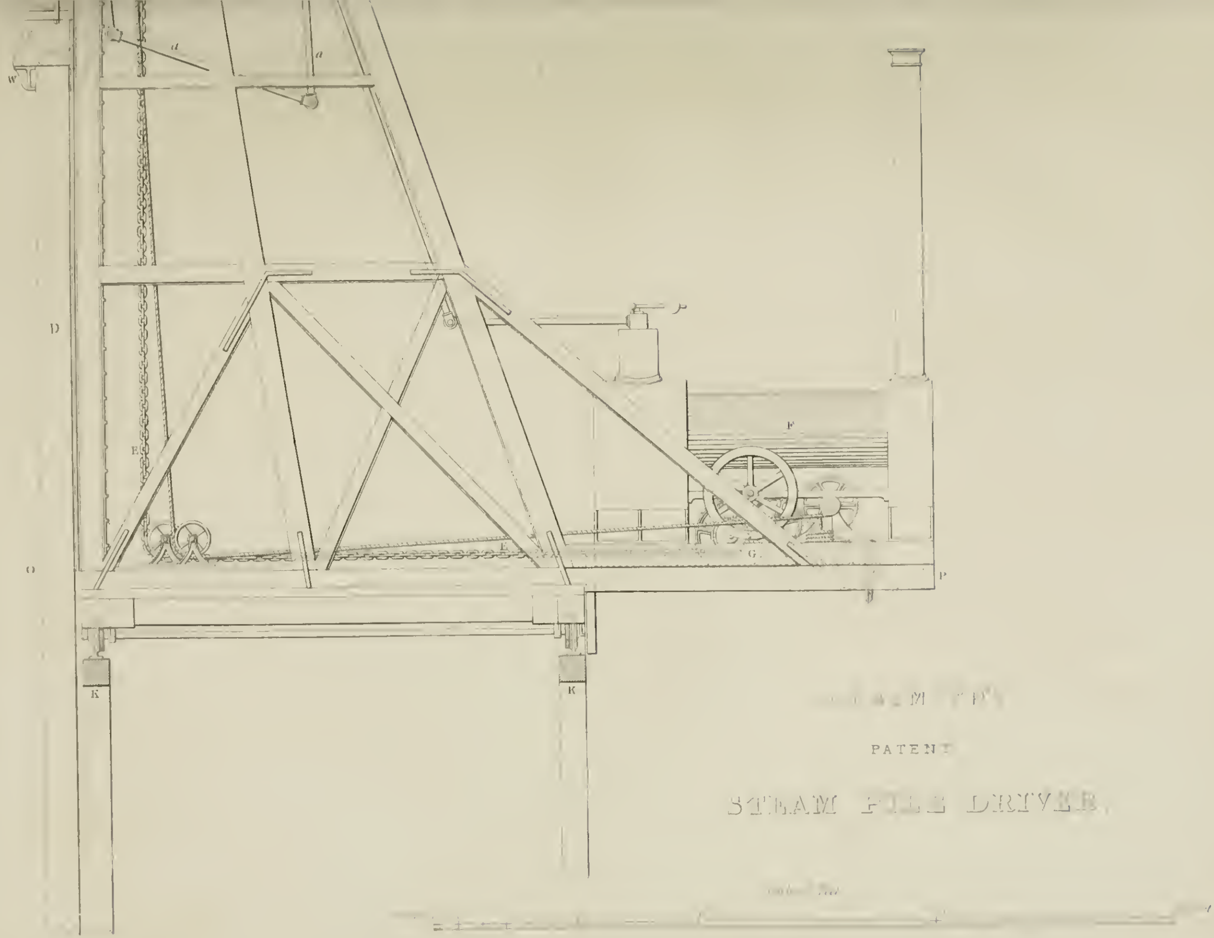


Fig. 3
Section
shewing Hammer raised



Inches 12 0 1 2 3 4 5 6 7 8 Feet



NASMYTH'S

PATENT

STEAM PILE DRIVER.

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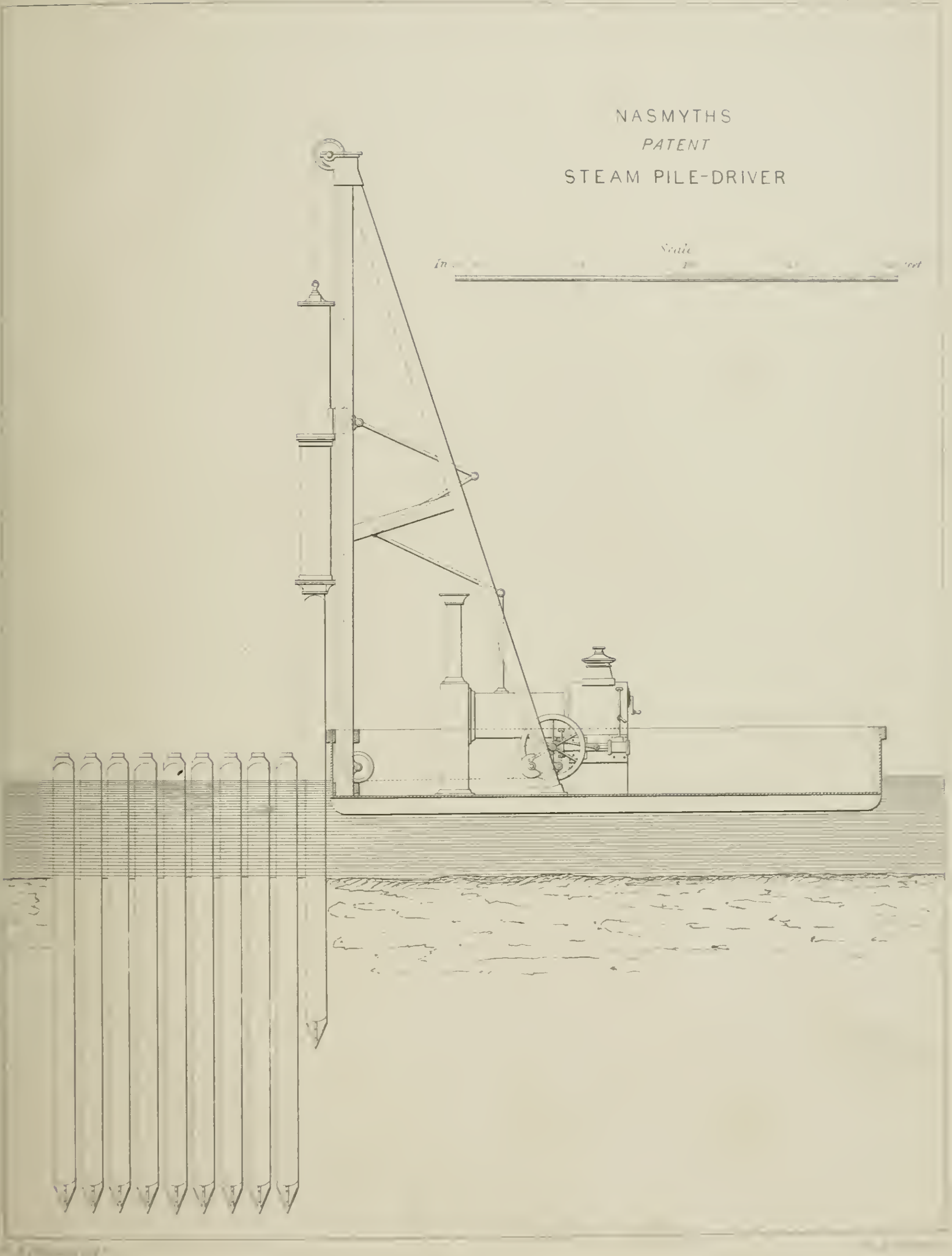
PLATE XXII^{a}

NASMYTHS
PATENT
STEAM PILE-DRIVER



[illegible]

is given, that the sense of sight cannot detect this action: the movement of the apparatus downward along with the pile is all but simultaneous. As in the case of the steam hammer, I have adopted exactly the same mode of uniting the piston rod with the hammer block, namely, through the medium of an elastic substance (poplar wood): this is seen in figs. 2 and 3, at P; and the expedient removes all ill effect of the concussion most perfectly.

James Nasmyth.

XI.—*Horizontal Loopholes.*

Horizontal loopholes present a much wider range of fire than vertical ones for the space exposed; and in boundary walls, defensible barracks and guard-houses, reverse fires, and caponnières, are decidedly preferable.

Plate XXIII. The present horizontal loophole (figs. 1, 2, and 3) is a cast iron frame, built into the wall so as to weaken it as little as possible.

It is adapted for a wall three bricks thick.

The same principle may be adopted in walls of any thickness.

Fishbelly girders (*a a a*) are provided to strengthen the upper part of the loophole, and enable it to carry the wall above. Arches however may be turned, as over window openings, if preferred. Half-inch iron will be sufficient for the sides and bottom of the frame.

By giving the loophole the present form, it sets with great firmness in the wall.

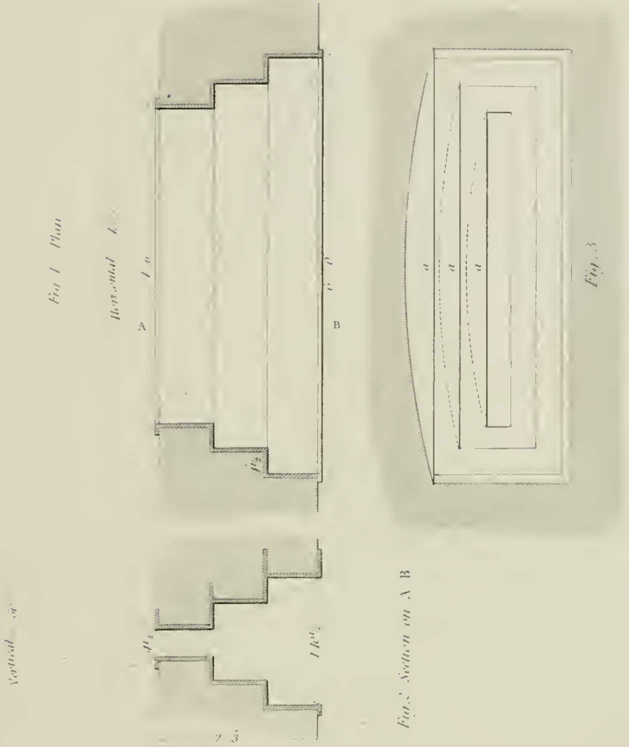
In reverse fires and caponnières, whose object is the defence of the passage of the ditch when the enemy is otherwise occupied than in returning the fire from them, external objects will be better seen by making the larger opening of the loophole *outside*, in which case the smaller opening may be increased from 4½ to 6 inches.

In boundary walls, barracks, and guard-houses, the larger opening should be inside: it will afford in the two latter more light, and provide shelves for the occupants; and in the former, it will present a smaller object, and make the opening higher from the outside.

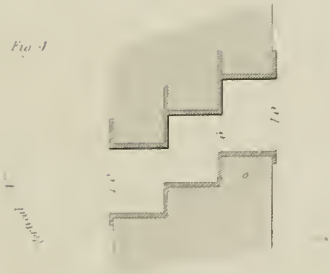
Loopholes should always be higher or lower than a man's height from the level of the ground immediately in front of them. When this cannot be effected, there should be a ditch in front.

Six feet is the length of the larger opening of the present loophole frame, which may be considered as a maximum, to be reduced according to circum-

PLAN SECTION & ELEVATION OF AN HORIZONTAL LOOPHOLE



SECTION OF A LOOPHOLE FOR HILL FORTS



Weight of 1 ½ inch Iron
cwt 5 0 15

J W Lowry fc

London Published by John Weale 59 High Holborn 18

stances. In towers or other works situated on high and commanding points, with no level ground within range, the section described by fig. 4 is recommended.

These loopholes, though here represented of cast iron, may also be made of large slate, or hard stone.

R. C. Alderson,
Lieut.-Colonel, Royal Engineers.

XII.—*Description of a Horizontal Loophole, and a Loopholed Window, proposed by Lieutenant-Colonel* Ord, *R.E.*

Plate XXIV. The accompanying plans of a loophole, and loopholed window, had their origin in the evident necessity that existed for some arrangement, by which defensible guard-rooms, rooms in towers, small posts, and buildings within barrack enclosures, &c., could be furnished with a reasonable supply of light and the warmth of the sun, where the other conditions connected with the defence of the post would render ordinary windows inadmissible, and loopholes imperatively necessary.

Such buildings are to be found in all parts on a very extensive scale, as now at Pembroke, and the common vertical loophole is as universally employed to admit its wretched light; and where these are used, the rooms are generally damp, which is as injurious to the health of the occupiers as detrimental to the building. From a view of Lieut.-Colonel Alderson's excellent proposition respecting horizontal loopholes, the present construction had its rise.

Figs. 1 and 2 represent a simple horizontal loophole for two men to fire through. They should be, when practicable, made of cut stone throughout,—if of brick-work, the head should be arched, as shown by dotted lines in fig. 4; the sides of common brick, and the soles of good hard Dutch clinkers, or fire-bricks (when manufactured of a hard nature), and set in cement.

All the four sides have one break, or return, offering an important obstacle to balls from without, whether from a direct fire, or after having been reflected from some other object.

The zigzagged loophole, fig. 3, is a plan that may be adopted with great advantage, where it is desirable, or even convenient, to have the mouth of the loophole towards the enemy, and which, in consequence of the numerous facets covered with sheet iron, will be found to afford scarcely less security than the plain-sided one, with the narrow opening outwards.

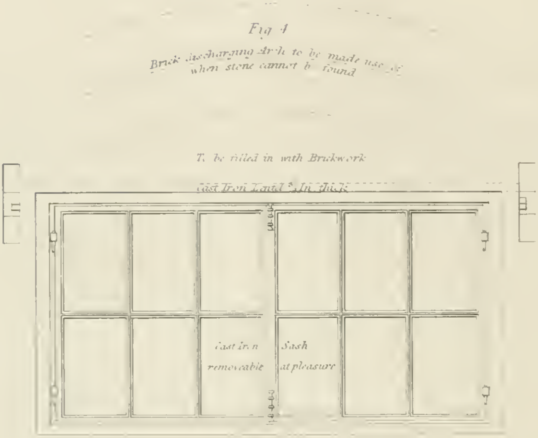
Note.—It is desirable that loopholes, in time of peace, should be closed near the outward edge by a piece of brick on edge walling.

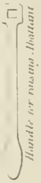
DETAILS OF A
LOOP-HOLE-WINDOW
FOR TOWERS, DEFENSIBLE GUARD-ROOMS &c.

12 9 6 3 0 1 2 3 fe

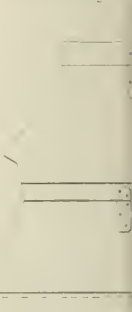
Interior Elevation

Fig 4


Brick discharging Arch to be made use of when stone cannot be found
To be filled in with Brickwork
Cast Iron Lintel ¾ In thick
Cast Iron Sash removeable at pleasure



Plan of falling Sh



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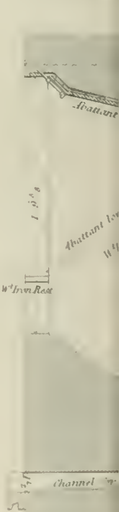
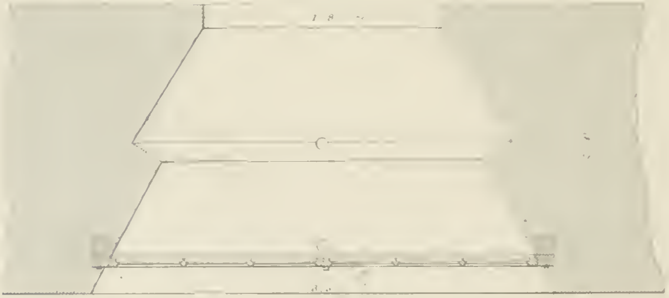


Plan

Fig 5

Exterior



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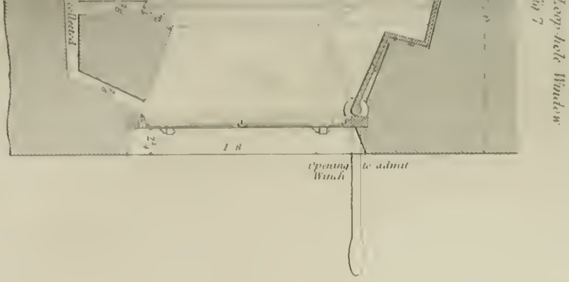
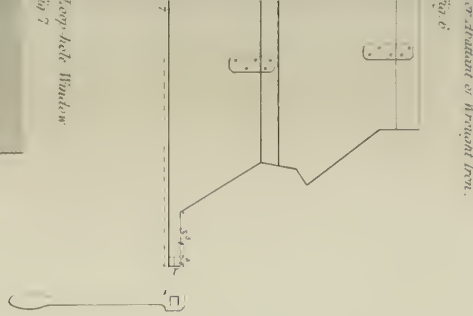
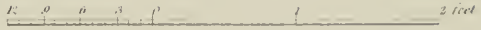




cale 59 High Holborn 1845

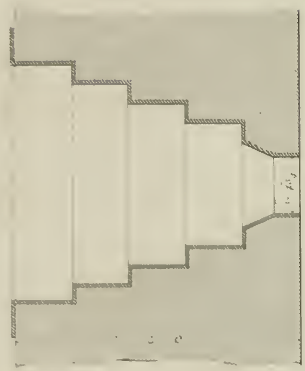
PLAN AND SECTIONS
OF HORIZONTAL
LOOP HOLES,

Scale of Feet



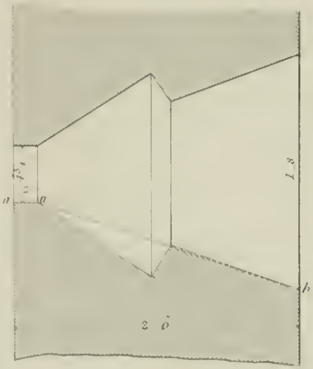
Vertical Sections through Loophole

Fig 3



[illegible] in Brickwork

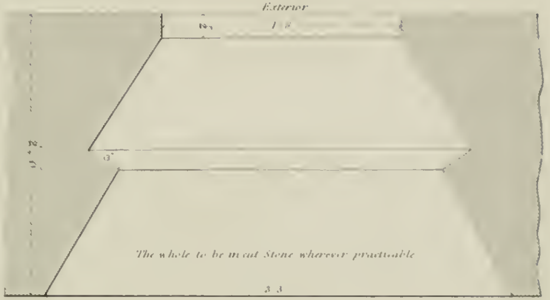
Fig. 1



If an enemy cannot fire in from above the dotted line a a b may be adopted with advantage

Plan

Fig



J.H. Lewis

Plate XII

Figs. 4, 5, 6, 7, represent the loopholed window. The dimensions, when the window is to be used as a loophole, are the same as those in figs. 1 and 2; and this is effected as follows:—A wrought iron abattant, or falling shutter, is attached to the head of the iron window frame, by means of a pivot or hinge, the two ends working in iron eyes or rings. The pivot is of round bar iron, with the sheet iron forming the abattant riveted to it. This abattant is lowered to the iron rests (see dotted lines in fig. 7), and thus forms a very complete loophole. When employed as a window, the abattant is raised by winch handles, which are fixed on the square ends of the pivot or hinge, and being bolted, remains continually up.

The iron sashes are removed for action, and the loophole is then clear.

By examining fig. 7, it will be clear that no injury can be done to the defender by shots between the abattant and the head of the window above it, unless the firing should be of such a nature that an ordinary loophole would be almost destroyed by it.

Plates are riveted to the angles of the abattant to strengthen it. The necessity for them, and their dimensions and numbers, would be left to the discretion of the engineer, as the strength required would of course vary according to the fire likely to be brought upon it, which would depend upon the locality.

This loopholed window should also be in cut stone whenever practicable.

This window may be lengthened to 6 feet when necessary (this length being the maximum), by dividing the sash frame into three compartments, and allowing the two end sashes to open, as the present sashes do; the third, or central one, being a fixture, except in case of attack, when it should be unbolted at top, and lifted out of its frame, into which it is fixed below by two small dowels. In this case, the opening being large, the head of the loopholed window might be supported by a small iron column, let into the stone at both ends. The abattant would then require a notch to be cut in its edge, to allow it to rise and fall past the pillar. More strength must be given to the abattant, of course: one more bolt would be required, and two semicircular hooks, or brackets, should be attached to the window frame to give support to the hinge, a hole being pierced through the flat part of the abattant, to allow the points of these hooks to pass as it rises and falls.

The figures show the walls as 2 feet thick, but the same principle may be applied to walls of every degree of thickness.

XIII.—*Proposed Mode of Constructing a Breakwater, and of Stopping the Movement of Shingle on the Sea Coast. By Major* YULE, *R.E.*

THE great expense of the ordinary mode of constructing breakwaters of masonry or of loose rock has led to the trial of other means of resisting the action of waves on sea walls, or in harbours.

Timber framed in various ways, both floating and fixed, has been adopted, it is presumed, without success, as no improvement on the ancient structure has been brought into general notice.

The substitute now proposed is on a different principle: it will also be easy of construction, easy to be repaired, and it will be applicable to every situation.

It is to meet the action of waves by rows of vertical floats, each having its own anchor: as these floats will not offer much resistance singly, they will not be liable to be displaced or soon worn out, but by dint of mere numbers, and by yielding to the force of the waves, they will break it.

This method has not been tested by experiment, but in its simple elements it is so analogous to a common production of nature, that little seems wanting in confirmation of its probable efficiency.

The structure is to consist of spars of light timber, such as young fir or larch trees, to be anchored by the stem, so as to float vertically.

The remblance to reeds, which is alluded to above, if it may not have suggested the original idea, is an obvious confirmation of the principle: they yield to winds and waves, and overcome both.

In the course of inquiries on the subject, a case was mentioned to me by a naval officer of high rank, in which he had found shelter behind reeds during a storm on one of the lakes in Canada: but reference can be made to classical authority, aptly confirming the principle already stated.

The port belonging to Pisa was formerly sheltered in a singular manner, as is related in Eustace's 'Italy,' vol. ii. page 272. "This port was protected neither by mole nor pier, nor indeed by any artificial or natural rampart of walls, rocks, or promontories. Though it was open to every wind, yet vessels rode secure on its bottom. The cause of this peculiarity was the size and tenacity of the weeds, which were so closely interwoven, it seems, as to exclude the agitation of the sea, while they yielded to the weight of vessels.

"Such is the account of Rutilius."[1]

If this project of the vertical floats should prove successful, it may admit of a more extended application.

It may be used in various parts of the coast in the South of England, to arrest the movement of shingle, which instead of being, as now, an impediment to the efficiency of harbours, may be made to contribute to their formation.

The structures hitherto used for the purpose are soon worn out by the attrition of the shingle; but in the manner now proposed, it would only be the first rows of the spars which would suffer from this cause: each row in succession would be less violently acted on, until the shingle be finally stopped.

If there is nothing scientific in the above suggestions, the same remark applies to the system of M^{c}Adam, which has produced smooth roads to the extremities of Europe. By means having the like quality of simplicity, smooth water may, it is hoped, be obtained on every shore.

PROPOSED DETAILS RESPECTING THE VERTICAL FLOATS.

1. It is proposed to have the vertical floats of young fir or larch trees, or spars, not exceeding 25 feet in length, this being about the greatest height of waves above their hollow; (see account of the Bell Rock Light-house, page 309; and vol. ii. page 128, of Professional Papers of the Corps of Royal Engineers.) The diameter of the spars to be nearly uniform, averaging not more than 6 inches, it being desirable that the floats with their anchors should be easily managed in lowering and raising them.

2. The anchors to be of stone, with iron rings fixed to them, to which the spars will be attached by means of two or three iron links, so as to admit the free vibration of the spars. The anchors will be of about 2 cubic feet content,

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[1] P. Rutilius Rufus was a Roman Consul 104 years B. C.

or as much more as on trial will be found sufficient to prevent them from dragging.

3. To meet the ground swell, any current, or disturbed action of the water below the level of the hollow of the wave, the spars to be lowered into the sea to the depth required.

4. When the floats are of equal length, and in the same depth of water, they will not, it is assumed, be liable in the course of their vibration to impinge and wear out each other, as the waves will affect adjoining ones alike.

5. It is impossible to calculate what number of floats will be sufficient, as I have not received the account, which I expected, of trials to be made in England, by which their size and the distance between them might have been decided.

I will assume the length of the breakwater to be 400 yards, and the distance between the spars to be 5 feet; the number in each row will be 240. Assume 200 yards to be the breadth, the number of rows will be 121, and the total number of spars 29,040. Call the price of each £1, then the cost of every foot in breadth of such a breakwater would be about £50.

6. The durableness of spars so anchored admits of doubt, but after their utility has been tested, hollow iron cylinders may be substituted, if cheaper.

7. With respect to the harbour at Pisa, the imitation of it is so obvious, that nothing more need be said than that a stout cordage, made of Sicilian grass, measuring 5 inches in girth, costs only about 2*d*. a fathom.

T. Y.

Note.—Since writing the above I have discovered that a proposition of a very similar nature was made by Major Parlby, who published it in No. 1039 of the Mechanics' Magazine.—T. Y.

XIV.—*Railways.* *By* G. Drysdale Dempsey.

(Continued from vol. vii. page 159.)

SECTION III.

RETAINING WALLS, BRIDGES, TUNNELS, &c.

Considered in its applications to railway service, the art of bridge building appears at once to demand and to be susceptible of being reduced to a system of proportions and strengths, combining all the solidity and durability that may be required with the utmost practical economy in cost. In preserving the essential conditions of the line, the number of bridges and other similar structures is necessarily much greater than would suffice for the same length of common road whose gradients and windings might range within much wider limits than those prescribed for locomotive transit. For every mile of railway hitherto constructed in Great Britain, from two to four bridges have been built; and many of these, it must be remembered, are not mere single-arch structures, but viaducts of hundreds of feet in length, of great height, and consequently great solidity and cost. It is evident therefore that a single item of defective design in these works entails most severe losses, either from excess of first cost on the one hand, or from expensive repairs and additions on the other; and, together with this occasion for scrupulous care and exactness in designing and executing these works, those which carry the railway appear to admit of calculations of the load they will be required to support, much more readily and exactly than ordinary road bridges, the load upon which is liable to all sorts of fluctuations.

This subject has of course occupied the careful attention of railway engineers, and the experience already obtained has produced many splendid examples, which unite sufficiency and economy in a high degree. Nevertheless, the former of these conditions is so much more readily seen and appreciated than the latter, that the "let-well-alone" theory cannot be trusted, and every one who receives the charge of railway works should feel himself stimulated to a thorough consideration of this subject.

Before directing the reader's attention to the several examples of bridges which have been collected for this work, I would beg, first, to recount the more prominent points for consideration in designing such structures; and secondly, to present a simple classification of the several varieties under which they may be arranged, according to the circumstances of each case. It would, of course, be equally beyond the pretensions of this descriptive sketch, and supererogatory as dedicated to the use of the Corps of Royal Engineers, to attempt any exposition of the theory of bridge building; but a brief outline of the several points of practical importance will, it is presumed, serve to facilitate the arrangements of the engineer, and may save the trouble of further reference. According to the order adopted at the head of this Section, we have first to regard

RETAINING WALLS.—The only cases in which artificial retaining walls appear desirable are those in which it is actually or nearly impossible to interfere with the surface, which would otherwise be required, in order to substitute cutting or embankment at the natural slope of the material of which they may be composed. Many instances are recorded of the failure of these structures, which has commonly resulted from the saturation and consequent swelling of the earth behind them; and these effects have occurred frequently, despite the most judiciously selected forms and materials, and the best attainable system of back drainage. Indeed, unless the material be adapted to stand by itself, be thoroughly impervious to water, or so completely drained that very little reaches the back of the wall, it is certain that this uncontrollable agent will make its way through the work, and produce sooner or later the disastrous consequences which have already marred the designs of railway engineers.

As applicable to cuttings, artificial retaining walls, unless they can be constructed under most favourable circumstances, are best secured by arches thrown between them, or by other intermediate resistances, which are required to act as abutments between the two walls, and prevent their forward movement towards each other. With this addition, it is evident that the structure becomes a bridge, or nearly assimilates to one, and is palpably inapplicable to very long walls, except at a tremendous cost.

As applied to the feet of embankments, where the material is of that cohesive but slippery nature that a simultaneous movement of the entire mass may be apprehended, low and strong retaining walls are useful, and present frequently a judicious expedient, although in many cases less advisable than piling or wattling. As protections against the sea, retaining walls to cover the lower or entire face of the embankment afford the best means, although frequently very expensive, of securing the stability of the work; but in all such and other cases, if any thing more than a mere breakwater or rude collection of heavy stones, the wall, sloping back to the embankment, becomes rather a facing of masonry than an independent construction, and contributes to the stability of the work only by its artificial cohesiveness and greater weight. Applied to the entire height of embankments formed to a steeper slope than that at which they would stand independently, retaining walls may be considered never advisable, and would be infinitely better abandoned for a cheap construction of viaduct.

When their adoption, however, becomes imperative, the stability of retaining walls will depend upon the nature of the soil behind them, and the means taken for its drainage; and upon the form of wall adopted, and the manner and materials of its construction.

The amount and kind of pressure of the earth against the wall which retains it are evidently affected by the angle of repose, or natural slope of the earth; also by the quantity of moisture it will imbibe, the proportion of this which it will retain, the extent to which its absorption of water will cause expansion of the mass, and by other circumstances.

The natural slopes of some kinds of earth have been observed experimentally, and are thus recorded.

1.	Fine dry sand	35° 30′
2.	Gravel (dry ?)	37°
3.	Loose shingle, perfectly dry	39°
4.	Common earth, pulverized and dry	46° 50′
5.	Ditto, slightly damp	54°
6.	Earth, the most dense and compact	55°

Of these results, No. 1 is the mean of experiments recorded by Rondelet, Barlow, and Hope;[1] No. 2 is on the authority of Lieut. Hope; No. 3 is recorded by General Pasley; Nos. 4 and 5 by Rondelet; and No. 6 by Barlow.

According to the specific gravity of these substances, it appears that the weight of the triangular section (one foot thick), which is bounded by the vertical back of a wall 10 feet high, a horizontal line level with the top of it, and the natural slope of the material, will be about as follows:

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[1] 'On the Pressure of Earth against Revetments,' by the late Lieut. Hope. Professional Papers, vol. vii. art. xi.

1. Sand	6800 lbs.
2. Gravel	6350
3. Shingle	8600
4. Earth, dry	4800
5. Ditto, damp	3700
6. Ditto, dense	3580

The mere weight of earth to be sustained thus appears to vary very widely according to its constitution and state of dryness or moisture; but this comparison of weights, forming only one element of the calculation, does not furnish any estimate of the actual resistance which the wall is required to exert. This will evidently be reduced by the cohesion of the moving mass, and by the friction between this mass and the natural slope of that portion which would remain stationary in the absence of the wall; but, on the other hand, it is increased in a great degree by the action of water within not only this moving mass, but also the otherwise quiescent mass beneath it.

In a state of perfect dryness, and disregarding the withholding effect of cohesion and friction, the maximum power required in the wall would be represented by the actual weight of the retained earth, supposing this weight to act against the vertical plane of the wall with the same force that it would exert upon a horizontal plane that supported it. And the power thus required in the wall might be immediately calculated for each section of its altitude; but the moment that water is introduced within the retained material, a multitude of other considerations arise, which no theory has yet furnished the means of estimating, and which require a series of experiments to enable us to predetermine with any chance of accuracy.

Upon the methods of draining retaining walls, reference may be made to the account of the Blisworth cutting, given in the second Section of this Paper;[2] also to the description of the mode of repairing the walls of the London and Birmingham Railway, contained in the seventh volume of the Professional Papers.[3]

Among the various considerations to be entertained in the designing of retaining walls, that of the influence of *season* should not be disregarded. A wall built during a dry season, or after a long drought, will incur an augmented pressure when the earth becomes saturated with water; and on the other hand, if built during a wet season, and backed up with wet earth, it will be subject to a shrinking away of this backing when subsequently drained. The engineer can provide against injury from these circumstances only by making the wall as far as possible self-supporting, so that any retiring of the earth behind shall not endanger its stability; and at the same time, offering every facility for the water to find its way through the wall, and for discharging it thence into the foundation drains. The most perfect wall would be that which should be throughout its whole surface completely permeable by water, so that no accumulation of that fluid could occur behind it, and which should yet effectually retain the particles of earth. Upon such a wall the effect of the earth would be reduced into that of its mere weight, and experiments would be needed only to determine the best arrangement of bricks and mortar, or other materials, for resisting this action.

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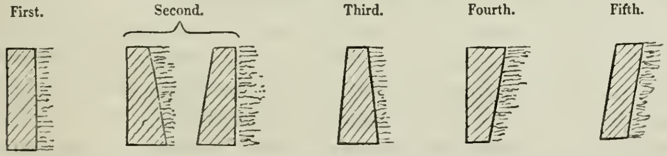
[2] Vol. vii. page 140.

[3] Art. xv. page 160.

As to the best and most economical *forms* for these walls, we are enabled to describe some which have been constructed, and have fulfilled the purpose of their construction, and we may also refer to the objections against some forms which have been suggested and adopted; but on this part of the subject experiments are also much wanted, and under this conviction, all must regret the premature loss of Lieut. Hope, whose skilful labours in this department promised so many valuable results to civil as well as to military engineering.

Of plane walls, five different forms have been constructed: first, having vertical faces; second, having one vertical and one inclined face, converging towards the top, and presenting either of these surfaces to the retained earth; third, having both faces inclined, and converging towards the top; fourth, having one vertical face, the other inclined and converging towards the bottom; fifth, having its faces inclined and parallel.



Each of these forms is sometimes varied, by curving the inclined lines: then, the second form will present a concave surface to the retained material, or otherwise a concave exterior surface; the third will have a concave surface towards the earth, and either a concave or a plane inclined exterior surface; the fourth form will have a convex surface against the earth, and a plane vertical surface externally; and the fifth form will present a convex surface to the earth, and a concentric concave surface externally.

Of these forms, the first three are evidently adapted to stand alone; while the fourth and fifth will depend for their stability partly upon the outward thrust which the retained material will exert against them.

It is frequently found that the middle or upper part of a retaining wall fails first, and will be thrust some inches forward, while the lower part of the wall remains firm. This occurrence, which, considering the greater weight opposed to the lower part of the wall, cannot be attributed to the mere weight of the earth, is probably owing partly to the superior strata being less dense, and therefore more rapidly saturated with water than the lower strata. This would lead to the necessity of providing especially for the complete surface drainage of the retained district.

In other instances of defect, the whole wall is moved bodily forward, and sometimes with very little fracture. This was the case with a portion of the wall built on the line of the Birmingham, Bristol, and Thames Junction Railway, which for a length of 40 or 50 yards was pushed forward off the foundation, to a distance of 8 or 10 feet, the wall still standing. This failure was pronounced by Mr. Vignoles, who examined the works at the time, to have resulted from the accumulation of water, which, "having no outlet, had settled the earth against the back of the retaining wall, turning the clay into mud, and by the great additional weight forcing it into the position in which it then appeared."[4]

There is no doubt that the ultimate stability of retaining walls is affected by the state of dryness of the masonry when the earth is filled in behind it; and also by the manner in which this filling in is conducted.

Upon the latter subject some valuable remarks were made by Mr. J. B. Hartley, in a Paper read before the Institution of Civil Engineers, in the session of 1841. From an abstract of that Paper, published in the C. E. and A. Journal, (vol. iv. p. 395,) the following may be usefully quoted.

"The author considers the method of filling *towards* the wall from the natural bank to be highly objectionable; the material lies in strata at the angle at which the deposit is made; as the quantity increases, the subsidence commences, and the earth slides downwards, throwing its whole weight against the back of the wall. The tendency to slide is frequently accelerated by the natural form of the ground upon which the earth is thrown, as it not unfrequently inclines towards the wall, in which case the pressure will necessarily be in proportion to the inclination of the slope, and the nature of the material of which the filling is composed. The wall at Hunt's Bank, on the river Irwell, is instanced as a failure of this description. The wall, about 100 feet in length, and 20 feet in height, 5 feet thick at the bottom, and 3 feet 6 inches at the top, built of ashlar masonry, strengthened by counterforts, was forced into the stream by the pressure of the earth behind it. With proper attention to the manner of filling in the different materials, a comparatively slight wall may be constructed to sustain a considerable weight of backing. The author lays down as a rule, that wherever it is practicable, all filling behind walls should be *commenced at the wall*, and be proceeded with from thence towards the solid ground, by which means the strata would be inclined in a similar direction: ledges or benches, either level or inclined in an opposite direction to that of the bank, should be cut in the solid ground to receive the filling, and counteract its tendency to slide. The weight should not be laid too quickly upon a new wall; and if with these precautions care be taken that the counterforts are constructed simultaneously with, and well tied into, the wall, a comparatively weak structure will bear a heavy mass of filling.

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[4] Civil Engineer and Architect's Journal, vol. v. page 95.

"The author gives as an example the retaining wall constructed on the west side of Jackson's Dam, near the Brunswick Graving Docks, Liverpool. This wall, although built of slight dimensions, and filled behind with material of the worst description, resisted perfectly all strain: this could only be attributed to the filling having been gradually done in the manner which the author's practice leads him so strongly to recommend."

Reverting to the *forms* for retaining walls, it may be remarked that a preference has been shown towards the fifth, with some little modification. By railway engineers this form is usually reduced in thickness at the top, by steps on the inner face. The experiments made at Dublin, under the direction of Sir J. Burgoyne and the Board of Public Works of Ireland, are quoted by Mr. Vignoles as fully proving that the "parallel battering-wall" is the one which offers the most support, with the least quantity of material. And one of the results deducible from the experiments instituted by the late Lieut. Hope, at Chatham, is in favour of the "leaning wall with counterforts." Lieut. Hope "conceived that the face of the revetment might be a mere shell, hardly exposed to any pressure, the earth being chiefly supported by its friction against the sides of thin but frequent counterforts."[5]

These results cannot however be admitted as conclusive against the several other forms which have been, in some instances, adopted. Thus the second form appears well adapted for stability, and has the advantage of an enlarged section below, and a reduced one above, from the same amount of materials as No. 5. Again, the third form appears to be very strong, and well adapted to escape injury from any extra pressure resulting from the absorption of water by the retained bank.

But it must be observed of the first, second, and third sections, that the inner face of all of them departs more widely from the natural slope of the earth, and therefore sustains a greater pressure than the inner face of section No. 5. Section No. 1 is evidently inferior, by reason of its uniform thickness, which must be either excessive at the upper, or deficient at the lower, part of the wall. This defect of uniform thickness is partly compensated in No. 5 by its inclined position, which gives it a tendency to fall back upon the earth, and thus resist its pressure.

The value of this fifth form of retaining wall appears to arise from the line of direction being thrown beyond the centre of the base, thus giving a preponderating weight within this line, the effect of which weight increases in proportion to the height of the wall and its divergence from the perpendicular. The angle of this divergence remaining the same, the height may be supposed to be reduced till the line of direction falls within the base, and the active weight of the wall becomes reduced to nothing; or, on the other hand, the height may be supposed to be increased until this active weight shall equal any pressure of the retained earth. And this consideration will perhaps partly account for some of those instances of movement in the *middle* or *upper part* of retaining walls thus formed, which are well known in practice, and which we have already had occasion to notice. In these cases we may imagine, that unless the construction of the wall is such as to insure a superior cohesion among its parts, the upper part of the wall will have a tendency to fall backward, while the lower part (of which the line of direction falls within its base) will have no such tendency. The upper part, obeying this tendency, becomes dislocated from the lower, and will be forced forward by the pressure behind it.

[5] Professional Papers, vol. vii. page 86.

The great importance, in works of this class, of judicious construction, not only in design, but also in practical execution, will justify the introduction of a few hints upon brick-work and bonding generally, especially as in all considerations upon those works we have to assume the perfect cohesion and entire rigidity of their parts ; and our conclusions will, therefore, be the more fallacious in proportion as these conditions are neglected and non-realized in practice.

In the first place, the arrangement of the bricks should be that known as *English* bond ; viz., one course of headers and one of stretchers alternately. The bonding of the plain part of the wall should be secured by introducing a half brick for every alternate outside header on both sides of the wall, so as to connect the outside headers with the bricks in the interior of the same course. At every fourth course, or thereabouts, three or four bands of iron hooping, laid parallel, and bedded in the joints, assist the bond. At each returning wall or counterfort, quarter bricks are required, in order to avoid straight joints on the face of the wall, and preserve the bonding at these angles. In all battering walls it is especially necessary to insist upon narrow joints perfectly filled with mortar, and truly pointed. This is the only means of guarding against, or rather deferring, that penetration by wet and frost which is so detrimental to the stability of the work. The bricks, too, should be thoroughly wetted before and during the setting, so as to detect any injurious quantity of limestone which may exist within them, and also to cleanse them and render the mortar thoroughly adhesive. In all cases the work should be brought forward simultaneously, or as nearly so as possible, throughout the whole length in hand, otherwise the shrinkage which invariably occurs will be unequal, and produce internal dislocations of the wall, which will accelerate, if not produce, ultimate failure. Similarly, all counterforts must be erected along with the wall itself, for all subsequent connections of these parts will be necessarily imperfect.

The concrete and lower courses of brick-work or footings should be deeply notched into the solid ground on the inner side of the wall. If this be carefully observed, and all spaces in the excavation or trench cut for putting in the foundations be well rammed, no movement of the foundation can take place without it be actually lifted to the extent of its entire depth, or without crushing the solid ground before it. In a similar manner, all the courses of brick-work should have a dip downwards from the outside face of the wall, and, in short, every possible means be adopted of connecting the entire mass of wall and foundations indissolubly together.

All reductions in thickness should be made in steps, keeping the intermediate sections of the wall parallel; for if any attempt be made to reduce by tapering lines, the restriction to proper sized bricks and parts of bricks is necessarily disregarded: bats, and pieces of every variety, size, and shape, are thrust in, so as to preserve the outside lines only; and good bonding and narrow joints are alike unheeded. And this forms a great practical superiority of the fifth form of wall over the second, third, and fourth. The fourth section, indeed, is otherwise so objectionable, that it can be selected only under the absolute necessity of preserving a vertical face, and a back inclined towards the natural slope of the retained earth.

A practical rule for a section of retaining wall which has in many cases proved sufficient, and has yet been deemed economical, is as follows:—let the batter equal one-sixth of the vertical height of the wall; the thickness of wall at the bottom equal one-fifth of this height, and the thickness at top one-tenth the height, or one-half the thickness at bottom: and for the reducing of the thickness, divide the entire height into as many equal parts, plus one, as there are half bricks in the difference between top and bottom thickness. Thus a wall 30 feet high will batter 5 feet, be 6 feet thick at bottom, 3 feet at top, and be divided into nine different thicknesses, each 4½ inches less than the lower adjoining one, and each 3 feet 4 inches in height, measured vertically.* Under ordinary circumstances, however, economy of material may perhaps be effected, or greater stability be secured, by reducing this thickness, and introducing small counterforts at frequent intervals.

BRIDGES, AND VIADUCTS.

During the development of the railway system in Britain, the economy of bridge building has necessarily received much attention, and has been illustrated by a multitude of structures, exhibiting many varieties of design and of material. That this vast experience has led to substantial improvements and to saving in cost, may be inferred from the fact, that in many cases bridges and viaducts of great extent are now adopted in preference to mere earth-works,—a long viaduct being now available at less cost, original and current, than an embankment of similar extent; whereas, in the early experience of railway making, it is well remembered that the most expensive earthwork was almost invariably adopted, both for economy and ultimate sufficiency, in preference to any description, then approved, of bridge-work.

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* This wall appears very light: a mean thickness of one-fifth of the height, or 6 feet, would be the minimum I should like to trust; and this would give the base 9 feet wide instead of 6 feet.—W. D.

In this sketch it is presumed that bridges and viaducts may be treated under the one common head,—bridges,—and with no attempt to distinguish between them, the one being deemed only a more extended form of the other.

The several cases in which bridges are required in railway works, and which may be judiciously treated with difference of design, of dimensions, and of materials, are intended to be indicated by the eight figures in Plate XXV. These are arranged in two classes, headed A and B; the one including bridges *under* the railway; the other, bridges *over* the railway. Each class comprehends four cases, viz.: First, where the levels of railway and of common road crossing are originally coincident. Second, where they differ just so much as will suffice for headway under the arch. Third, where they differ to any great extent beyond the required headway; and, Fourth, where they differ less than the required height.

In the eight figures on Plate XXV., it should be observed that L.R. signify *level of rails;* O. S., *original surface;* and A. S., *altered surface.*

In the first case, the required crossing may be obtained either by cutting deep enough to get height for the common road traffic below the railway, and cutting inclined approaches, thus lowering the road level; or it may be obtained by elevating the road level, throwing a bridge over the line, and making embanked approaches to the summit of the bridge. If the selection between these be within the engineer's power, several considerations will occur. As regards earth-work, the one design will *produce* nearly the same quantity of material that the other will *consume;* the one or the other will therefore be desirable, according as there may be a deficiency or excess of earth in the adjoining parts of the line. In economy of brick-work, the bridge in cutting has the advantage, as the footings require to be sunk only 18 inches or 2 feet below the slope; while the bridge in bank (as shown at B, fig. 1) will require the abutments so much below the original surface. The latter will also require fences on the approaches, which the former will not. On the other hand, the bridge in cutting will involve more expense in drainage than the bridge in bank; and this consideration must be entertained with full regard to the comparative levels of the surrounding districts, and will frequently be found to outweigh all the other advantages of the sunk bridge. In either bridge, wing walls may be well dispensed with; the abutments should be allowed to cut into the bank or the slope, and be lightened as much as possible by side arches and by arched openings, with inverts in the cross section.

In the second case, the road crossing is supposed to be required at a point where the railway is either in an embankment of about 16 feet high, or a cutting of about 16 feet deep. In either instance, the best structure will be obtained by adopting a bridge with parapets parallel throughout, or very slightly diverging from each other at each end; by making it sufficiently long to allow easy slopes for the banks, an ample width of road, and for the abutments to cut well into the slopes on each side; thus dispensing altogether with wing or retaining walls, which are always expensive, and seldom secure.

In the third case, where the difference of levels is very considerable, and an extended structure or viaduct is required, economy of construction becomes additionally important. A reduced width of viaduct, so as to provide for one line of rails only, has been sometimes recommended; but this is a kind of economy which can be justified only under peculiar circumstances, and which may be productive not only of much inconvenience and hindrance, but of greater ultimate expense than the double width would at first involve.

For structures of this magnitude, the sufficiency of foundation is of the first importance; the greater altitude not only imposes greater weight of materials to be supported, but also evidently requires that the cohesion of the foundations, and indeed of the whole structure, be more perfect, as any defect or dislocation is more likely to occasion extensive mischief in proportion as the height is increased. If gravel or chalk can be reached, with a good bed of concrete nothing need be apprehended; but if loam, sand, or bog occurs, piling is found the better expedient. Upon a good foundation, piers and arches may be constructed of a light, yet sufficient and economical character. The late use of timber for works of this class has much reduced their cost; but experience has not yet been had which would warrant the assertion, that the expense of current repairs may not, in some instances, outweigh the economy in first cost. The prominent advantages of timber for works of this class, as applied in the timber-arched bridges, are,—the large spans which may be adopted, thus reducing the number of piers required,—the comparative lightness of the whole structure,—and the facility and rapidity of erection. Much less scaffolding is needed in building these timber bridges than in building those of masonry; less time is required for the consolidation of the materials; and in most districts, timber, and workmen for fashioning it, are so much more readily and cheaply procurable than stone or bricks, and masons, that some overwhelming objection must be proved in order to justify the abandonment of the former material. This objection has been foreseen by some persons in the anticipated rapidity of decay of some of the parts of timber bridges, and in the difficulty of replacing such parts, and effecting the necessary repairs.

In the district between Newcastle and North Shields, two viaducts have been constructed of timber by the Messrs. Green, the total cost of which was about £48,000; and it has been estimated that the saving effected by using timber instead of stone amounted to £14,000. In one of these viaducts, that over the Ouse Burn, Mr. B. Green states the amount saved was £9000. Mr. Mitchell, who about sixteen years ago erected a timber bridge over the Spey, having one arch of 100 feet span; and subsequently another having two arches of 100 feet span each, with stone abutments and piers; and a third across the Dee, of five arches of 75 feet span each, with timber piers,—states that timber bridges are one-third less expensive than those of masonry; and if built with timber piers, as in that one over the Dee, the saving amounts to one-half. Mr. Mitchell further states the period of their duration to be from 30 to 40 years, but does not furnish data for estimating expense of current repairs. Mr. Vignoles compares the Ribble viaduct, on the North Union Railway, with a timber viaduct. The former, he states, cost £60 per lineal foot, while the latter would cost only £20 per lineal foot; the Ribble viaduct being only 50 feet high, with five arches of 120 feet span, and the timber viaduct 100 feet high, with arches of 130 feet span, the width of roadway in both cases being 28 feet. These comparisons of cost depend, however, so much on the relative facilities for procuring and working each material respectively, that no general estimate can be offered of the advantage to be gained in this respect by the adoption of either.

The particular construction of timber bridge referred to already as having been applied upon the Newcastle and North Shields Railway, was described by Mr. B. Green, in a Paper read before the Institution of Civil Engineers, in March, 1841. Two viaducts have been mentioned, built by the Messrs. Green, described severally as the "Ouse Burn" and the "Willington Dean." Mr. Green's Paper referred particularly to the former viaduct: Plate XXXII. exhibits in detail the construction of the arches and piers of the latter, but as both viaducts are exactly similar, with only trifling differences of dimensions, the following abstract of Mr. Green's description will be equally illustrated by the same Plate.

"Mr. John Green, in the year 1827, made a design and model for a bridge, with timber arches resting upon stone piers. In 1833 the plan was adopted, and in 1837 it was put into execution at the Ouse Burn viaduct, where the construction was of great extent, and the cost was an important consideration. The viaduct is 918 feet in length, and 108 feet in height from the bed of the river. There are five arches, the versed sine 33 feet, and the radius 68 feet; three of them are 116 feet span each, and two are 114 feet each: two stone arches, of 40 feet span each, have been introduced at each end, to give length to the abutments, and to prevent the embankments from being brought too near to the steep sides of the ravine. The piers are of stone: the springing stones for the three ribs, of which each arch is composed, are on offsets, within 40 feet of the top of the piers; cast iron sockets are there bedded in the masonry, and secured so as to receive the feet of the ribs. Two of the piers are placed upon piles; the others are founded upon the rock: immediately beneath the centre of one of them an old coal-pit shaft was discovered, and close adjoining to it the remains of the working of a coal seam: both were rendered secure by being filled up with grouted rubble masonry. The ribs for the arches are composed of planks of Dantzic deal (Kyanized): the lengths vary from 46 feet to 20 feet, by 11 inches wide and 3 inches thick: they are so disposed, as that the first course of the rib is two whole deals in width, the next is one whole and two half deals, crossing the joints longitudinally as well as in the depth. Each rib consists of fourteen deals in thickness, bent over a centre to the required form, and secured together by oak trenails, 1½ inch in diameter, at intervals of 4 feet apart, each trenail traversing three of the deals. A layer of strong brown paper, dipped in boiling tar, is placed between the joints, to bed them and exclude the wet. Trussed framings and beams are secured upon the arched ribs; the platform, composed of planks, each 11 inches wide by 3 inches thick, is spiked down and covered with a composition of boiling tar and lime, mixed with gravel in laying on, forming a coating impervious to the wet: upon this platform the two lines of railway are laid, leaving a footpath between them. The centering for turning the ribs was very light and simple, and as every convenience was afforded by having a railway with travelling cranes along the sides of the piers, a whole centre could be moved by twenty men from one arch, and fixed in another, in one day." In a conversation which followed the reading of this Paper, Mr. Rendel remarked, that from experience he could not recommend either paper or felt between the joints, as therein described. "He found that both substances prevented the intimate contact of the surfaces of the timber; in all framings exposed to the action of the weather, the tar was absorbed by the wood; the paper and felt then became saturated with and retained the moisture, so that decay very speedily ensued. The mode he at present adopted was to have all the joints and mortises of the framings very closely fitted, leaving only sufficient space at the edges to be caulked with oakum, and the joint run with pitch, like the seams of the deck of a vessel. Wherever it was practicable, great advantage would result from covering the joints with sheet lead, to exclude the moisture and prevent the decay, which was the great bar to the more general use of timber in many engineering works." And Mr. Macneill stated that he "had found constant trouble to result from the decay of wooden bridges. The Dalmarnock bridge, which had been erected about thirty years, now demanded continual repairs; the struts were nearly all decayed at the point of insertion into the cast iron sockets. The original floor had been replaced by one of teak wood."[6]

As the building of the bridge here instanced by Mr. Macneill was anterior to the use of the wood-preserving processes now adopted, it may be questioned how far any of these processes might have arrested the course of decay. It may perhaps be also considered whether their contact with the cast iron sockets may have affected the soundness of the struts, and if so, in what degree.

Although a detailed examination of the several methods which have been latterly adopted for the preservation of timber would be out of place here, yet a condensed notice of some of them, and of the observations recorded upon their results, seems necessary in order to point to the evidence on which the extensive use of this material in railway viaducts and bridges is desirable or otherwise. The great economy, in first cost, of preferring timber to masonry both for long viaducts of small elevation, and for shorter ones of great height, is so far an established fact, that in all cases where this kind of economy is imperative, no discretion will be permitted in the choice of material, and the greater question—can wood be so far preserved as to make its employment desirable with a view to ultimate economy?—will be cast aside for the minor one—how can wood be the best preserved? But whichsoever of these questions has to be considered, the subjoined evidence will, it is believed, be equally useful.

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[6] Report in 'Civil Engineer and Architect's Journal,' vol. iv. p. 284.

The four processes which have been most prominently brought before the notice of the profession, are those known as Kyan's, Burnett's, Bethell's, and Payne's.

Kyan's process, secured by patent, March 31st, 1832, for preserving wood, consists in immersing it in corrosive sublimate or bichloride of mercury, until the wood becomes as far as possible saturated. In the year 1705, M. Homberg stated, before the Royal Academy of Sciences at Paris, that "a person of quality in Provence, not knowing how to preserve inlaid work, from the worms destroying it in a few years, as it frequently happens in that country, he had advised him to steep his inlaid work in water wherein corrosive sublimate had been mixed, which succeeded very well."[7]

"In the valuable work upon the dry-rot, published by Mr. Knowles, Secretary of the Committee of Inspectors of the Navy in 1821, corrosive sublimate is enumerated among the chemical substances which had been prescribed for preventing the dry-rot in timber; and it is well known that Sir H. Davy had, several years before that date, used and recommended to the Admiralty and Navy Board, corrosive sublimate as an anti-dry-rot application."[8]

The process of saturation under Kyan's patent was carried on in open tanks. Those erected for the Great Western Railway Company, at Bull's Bridge, near West Drayton, were 84 feet long and 19 feet wide at the top, 60 feet long and 12 feet 8 inches wide at the bottom, and 9 feet deep. The sides were of American pine plank 4 inches thick, supported on sills 12 inches by 10 inches, and upright framing posts 10 inches square. Ten of these posts were fixed in the length of the tank on each side, with diagonal braces 8 inches square. The tank was sunk in the ground, nearly level with the surface. The posts stood 2 feet above the sides, and transoms 15 inches by 12 inches were attached to them, to keep the timber down in the solution. Yet its tendency to float was so great that the transoms became cambered up 1½ inch in the centre, and in one instance the whole tank was disturbed from its seat. A mast with a traversing boom was erected at one end of the tank, and used in removing the timber.[9]

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[7] 'Memoirs of the Royal Academy of Sciences at Paris,' from 1699 to 1720. Vol. ii. p. 223.

[8] Ure's 'Dictionary of Arts,' &c., third edition, p. 811.

The solution used for preparing the timber contains 224 lbs. of the corrosive sublimate to 1062 gallons of water, or about 1 lb. to five gallons. The cost of the process was stated, in 1836, to be twenty shillings per load of 50 cubic feet. Of this twenty shillings, one-half consisted of license, risk, and profit, and one-fourth was estimated for labour in filling and emptying the tank, and unloading. The remaining fourth part was for cost of the solution.[10] The sublimate was dissolved in hot water, and added to the water in the Great Western tanks just described, and the strength of the solution was tested with the hydrometer.

Subsequently, attempts were made to improve the efficiency of the solution by *forcing* it into the wood, instead of simply immersing the wood in the solution. For this purpose close tanks were substituted for open ones, and an injecting apparatus of force-pumps, &c., was added, besides air-pumps for previous exhaustion. A complete arrangement of this kind was fitted up for preparing the timber of the permanent way of the Hull and Selby Railway, and was fully described before the Institution of Civil Engineers in March, 1842. The following is quoted from the Report of this Paper, published in the 'Civil Engineer and Architect's Journal.'[11]

"The apparatus consists of two tanks, a reservoir, two force-pumps, and a double air-pump. The tanks are cylindrical, with flat ends, and are made of wrought iron plates nearly half an inch in thickness; they are 70 feet in length, and 6 feet in diameter: at each extremity is a cast iron door, flat on the outside, and concave on the inner side, provided with balance weights for raising and lowering it. Each end is strengthened by five parallel cast iron girders, whose extremities are held by wrought iron straps riveted on to the circumference of the tanks. Notwithstanding the great strength of these girders, several were broken by the pressure applied during the process. The vessels are lined with felt, upon which is laid a covering of close-jointed fir battens, fastened with copper rivets: this precaution is necessary to prevent the mutual deterioration which would arise from the contact of the iron and corrosive sublimate. There was originally only one brass force-pump, 2 inches diameter and 6 inches stroke: this being found insufficient, another was added of 4 inches diameter, and henceforward a pressure of 100 ℔s. per square inch was easily obtained. The air-pump is 10 inches diameter and 15 inches stroke. Its construction is of the ordinary kind. The process is simple and rapid: the corrosive sublimate is first mixed with warm water in a trough, in the proportion of 1 ℔. of the former to two gallons of the latter; the clear solution is then poured off into the reservoir, where water is added till it is diluted to the proper point, which may be ascertained by an hydrometer: a more perfect test is the action of the solution upon silver, which it turns brown at the requisite degree of saturation. The operations of exhaustion and pressure employ eight men for five hours, the whole process occupying about seven hours, during which time from seventeen to twenty loads are Kyanized in each tank. It is desirable that the timber should remain stacked for two or three weeks after Kyanizing before it is used. It was found that about ¾ ℔. of corrosive sublimate sufficed to prepare one load (50 cubic feet) of timber. About 337,000 cubic feet of timber were Kyanized, the average expense of which, including part of the first cost of the tanks, was about *5d.* per cubic foot. The timber was tested after the process, and it was found that the solution had penetrated to the heart of the logs."

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[9] 'Civil Engineer and Architect's Journal,' vol. vi. p. 205.

[10] Ibid.

[11] Vol. v. p. 202.

The reading of this Paper was followed by a discussion upon the quantity of the solution absorbed by the wood, with and without the preliminary process of exhaustion, as practised for the Hull and Selby Railway; but in the absence of recorded experiments in which all other circumstances were the same, no agreed result was arrived at. The necessity of filling the pores of the timber, in order to make the process fully efficient, and the great difficulty of doing this by reason of the moisture which they already contained, was generally admitted. It was remarked also that the sublimate entered the *extremities* of the sap-vessels without pressure, but required pressure in order to penetrate *laterally*. Mr. Thompson, the Secretary to Kyan's Company, stated with regard to the strength of the solution, that "it was at first believed that 1 ℔. of corrosive sublimate to 20 gallons of water was sufficiently strong, and much timber had been so prepared; but experience had since proved that the strength of the mixture should not be less than 1 ℔. to 15 gallons, and he had never found any well-authenticated instance of timber decaying when it had been properly prepared at that strength: as much as 1 in 9 was not unfrequently used. In a cubic foot of wood prepared under a pressure of 70 ℔s.

per square inch, mercury had been found by the galvanic battery to have penetrated to the heart." The destructive action of the sublimate upon iron was also referred to.

The great want of complete experiments upon the peculiar action of this and other preserving matters upon timber, and the best mode of administering them, is apparent, and with particular reference to the adoption of timber as a material for railway viaducts and works. These experiments, it may be suggested, should also seek to determine how far the strength and elasticity of the timber is affected or impaired, according as the preparations are applied at the ends of the pores, so that these may become filled without crushing the intermediate fibres of the wood; or driven laterally into the pores through the resisting fibres.

With reference to the durability produced by this process, accounts are somewhat contradictory. How far success in this respect may be owing to careful and complete performance, or, on the other hand, failure be promoted by careless and incomplete Kyanizing, we have no means of determining. Upon the application of the process for the Great Western Railway, it was reported in August, 1843, that a part taken from the centre of one of the longitudinal timbers forming the base of the railway which had been Kyanized six years before, was "as sound as on the day on which it was first put down." But the reporter remarked, that during the process the strength of the solution had been carefully maintained. Upon first immersion the strength was 1 in 14, at a temperature of 62°; and the time of immersion for 7-inch timber was eight days: during this time the solution was kept at an uniform strength by pumping.[12] In this manner upwards of 40,000 loads of timber had been prepared, and the quantity of sublimate consumed was about $1\frac{1}{3}$ ℔. to each load.[13]

On the London and Birmingham Railway, on the contrary, the engineer reported, that the sleepers, which were all Kyanized, were, after lying three years, found to exhibit symptoms of decay,—that many of them had been removed absolutely rotten, and Kyan's process had been consequently abandoned.[14]

Sir William Burnett's process for preserving timber (patented March 19, 1840) consists in impregnating it with water saturated with the chloride of zinc. This is mentioned by Dr. D. B. Reid, in his 'Illustrations of Ventilation,' as the " most powerful of those materials that do not affect the texture or other qualities of the wood." And Dr. Reid adds that he has not yet " seen any specimens of wood or canvass that have resisted such trying circumstances as those that were protected by the muriate of zinc."[15]

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[12] In open tanks, the timber being subjected to simple immersion, without exhaustion or pressure.

[13] 'Civil Engineer and Architect's Journal,' vol. vi. p. 356.

[14] Ibid. vol. vi. p. 306

In July, 1841, Messrs. Lang and Abethell, of Woolwich Dockyard, reported that three specimens of wood, viz., English oak, English elm, and Dantzic fir, which had been prepared by this process, had remained in the fungus-pit at Woolwich Dockyard for five years, and were still perfectly sound; while three similar specimens unprepared were all more or less in a state of decay.

The cost of this process, as announced by the Association formed for carrying it out, is as follows:

For preparing timber, round or square, including planks, deals, hop-poles, paving blocks, and railway sleepers, at the Company's station, Millwall,—fourteen shillings per load of 50 cubic feet, besides two shillings for landing and loading. One pound of the material which the proprietors supply for one shilling is said to be sufficient for ten gallons of water.

Bethell's process (patented July 11, 1838) is described by Dr. Ure[16] to consist in " impregnating wood throughout with oil of tar, and other bituminous matters, containing creosote, and also with pyrolignite of iron, which holds more creosote in solution than any other watery menstruum. The wood is put in a close iron tank, like a high-pressure steam boiler, which is then closed and filled with the tar-oil or pyrolignite. The air is then exhausted by air-pumps, and afterwards more oil or pyrolignite is forced in by hydrostatic pumps, until a pressure equal to from 100 to 150 ℔s. to the inch is obtained. This pressure is kept up, by the frequent working of the pumps, during six or seven hours, whereby the wood becomes thoroughly saturated with the tar-oil, or the pyrolignite of iron, and will be found to weigh from 8 to 12 ℔s. per cubic foot heavier than before."—" The effect produced is that of perfectly coagulating the albumen in the sap, thus preventing its putrefaction. For wood that will be much exposed to the weather, and alternately wet and dry, the mere coagulation of the sap is not sufficient; for although the albumen contained in the sap of the wood is the most liable and the first to putrefy, yet the ligneous fibre itself, after it has been deprived of all sap, will, when exposed in a warm damp situation, rot and crumble into dust. To preserve wood, therefore, that will be much exposed to the weather, it is not only necessary that the sap should be coagulated, but that the fibres should be protected from moisture, which is effectually done by this process."—"The materials which are injected preserve iron and metals from corrosion; and an iron bolt driven into wood so saturated remains perfectly sound and free from rust. It also resists the attack of insects."—"The expense of preparing the wood varies from 10*s*. to 15*s*. per load, according to situation and distance from the manufactories where the material is made."—"Common Scotch fir sleepers, which have been in use three years and upwards, look much better now than when first laid down, having become harder, more consolidated, and perfectly water-proof."

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[15] 'Illustrations of Ventilation,' p. 74.

[16] 'Recent Improvements in Arts, Manufactures, and Mines,' 1844. p. 274.

At a meeting of the Institution of Civil Engineers, in February, 1842, it was stated, that some piles at New York which had been saturated with coal-oil, perfectly resisted the attacks of the 'Teredo navalis,' in the same situations where Kyanized piles had been entirely destroyed by them. And Mr. Bethell, the patentee of this process, remarked upon the necessity of purifying the oil of tar from ammonia, that "in experiments he had made previously to taking out his patent for preparing timber with coal-oil, he observed that wood coated with common coal-tar soon turned brown, and decay ensued; ammonia produced the same appearance and effect. The refined coal-tar, as manufactured in London, is purified from ammonia by distillation, and found an excellent coating for wood."[17] The process has been adopted in preparing the sleepers for several of the railways, and on one or more has been substituted for Kyan's process.

Payne's process is described in the patent (dated July 9, 1841) to consist in impregnating the wood, or other vegetable substances, with a solution of metallic or earthy matter, by means of exhaustion and pressure; and then, by chemical decomposition, obtaining the preserving matters in an insoluble state, within the substance of the vegetable material under operation. As there are many metallic and earthy matters which are known as preservatives of vegetable substances from decay, and from burning with flame, the patentee does not confine himself to any particular solution; but in order to illustrate his invention more clearly, he states, that (with respect to metallic solutions) if the vegetable matter be impregnated with a strong solution of sulphate of iron, either hot or cold, he forces into it, by exhaustion and pressure, a solution of any of the carbonate alkalies, or of any other substance that will decompose the salt, and render the oxide of iron insoluble. With regard to earthy matters, supposing the vegetable material be impregnated with a strong solution of alum, he decomposes it by the employment of a solution of carbonate of soda, of a suitable strength for that purpose ; or any other well-known means of decomposing the solution may be used, for the purpose of precipitating the alumina.[18]

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[17] 'Civil Engineer and Architect's Journal,' vol. v. p. 169.

This invention has been applied in preserving the timber used in the Royal stables at Claremont, and has been approved by the Commissioners of Woods and Forests, who directed Mr. Phillips, Professor of Economic Geology, to report upon the process. This Report was highly favourable to the utility of the invention.

Reverting to Plate XXV. of outlines of bridges, the situation for a railway bridge, shown in the figures 4, (A and B), supposes that the extent of embankment or excavation is insufficient for the minimum height under the arch, and that hence a small quantity of earth-work will be needed in cutting, as shown at A, fig. 4,—or in approaches, as shown at B, fig. 4. Of such bridges an example or two will be found in the description of Plates.

For the purpose of forming a road of any kind beneath a high embankment, the viaduct may be commonly dispensed with, and a low tunnel-like bridge be adopted, having only the minimum height of arch. Of such bridges an example is given in the Plates. It may be remarked here, that considerable saving is effected by adopting them. Although the narrow cut through the base of the embankment requires, in order to support the sides, that the wing walls of the bridge be extended to the entire width of the bank, yet the quantity of masonry is much less than in an equivalent viaduct; and it may also be judiciously constructed in a rougher and cheaper manner. In these bridges it is however highly essential to secure an ample thickness and strength of arch, and also to employ cement in the building of it.

The accompanying Plates represent some of the most substantial and approved works included under this Section.

Plate XXVI.—Figs. 1 to 5 refer to a double-arched bridge, built at a small angle over the London and Birmingham Railway, and carrying a public road or

street. The bridge is extended for a considerable length in the direction of the railway. Fig. 1 shows half the elevation. Fig. 2, half section, parallel with the face of the bridge. Fig. 3 is a partial plan, showing the lower part of the abutment wall, and is taken sectional through the intermediate piers which support the common impost of the two arches. Fig. 4 is a partial cross section through the crown of one of the arches, showing the construction of the arch, and parapets, and also showing the skewed backs from which the brick-work of the arch springs. These are cut upon the impost, and to the length of one or more bricks, so as to work in with the regular courses, and avoid the defective alternative of starting the arch with cut bricks and bats. Fig. 5 shows a portion of a similar cross section, having the recesses in the face of the abutment formed with inverts upon the face, and breaking the top line of footings. The footings of the abutments and piers are built upon a solid bed of concrete, about 18 inches thick. Against the elevation of this bridge a section is shown of the retaining wall, which bounds the cutting over which the bridge is built. The section, fig. 2, shows the manner in which the thrust of the arch, which is elliptical, having a rise of nearly a quarter of the span, is intended to be partly resisted by the solid ground adjoining, instead of being wholly sustained by the abutment. For efficiency this plan may be safely recommended; and as a judicious mode of rendering a flat arch safe, and thus dispensing with unnecessary height, this cannot perhaps be replaced by any cheaper method. In figs. 1 and 2 is also shown the dipped form to which the upper surface of the excavation should be trimmed, to keep the foundations dry, and lead the water towards central drains, as shown on Plate XXXIX. vol. vii., and described at page 156 of that volume.

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[18] 'London Journal of Arts,' vol. xxiii. p. 352.

Figures 6 to 10 represent a small occupation bridge, adapted for the convenience only of cattle or cart-traffic.

Fig. 6 is a half section, and fig. 7, a half elevation. Fig. 8, a partial cross section. Fig. 9, a partial plan above the foundations. Fig. 10, a section of one of the wing walls, taken near the abutment. This tunnel-like bridge is adapted for any extent of embankment, with the precaution, if of great height, of giving the arch a little extra thickness, and strengthening it by a tie-bolt built in the crown of the arch throughout its entire length, and abutting by heads, screwed nuts, or keys, against its two faces. This bolt may for convenience be formed in links with secure weldings. The roadway beneath the bridge, 15 feet wide, is shown as divided into a cartway and a footway. An inverted arch is turned in cement between the abutments, and cannot be well dispensed with in bridges built in such situations as here described. In these bridges the use of wing walls is imperative, unless the arch were carried forward to the extent of the bank, which would involve an unjustifiable expense; but if built of the strength shown in this example, these walls are fitted to answer their purpose in the best possible manner.

Figs. 11 to 15 exhibit a cattle bridge only, with brick arch, but faces entirely of stone, and thus adapted for a district where this material is plentiful. It is shown as if constructed in a bank about 9 feet high, but would require no modification except a thickening of the arch if built under a much higher one: a 9-inch invert is built between the abutments. The wing walls are shown as also faced with stone in courses.

Plate XXVII. represents two bridges built in rather different circumstances, but still sufficiently similar to admit a comparison between them of two styles of design, both of which have been much employed in railway bridges, viz., the single-arch with long wing walls, and the three-arch with intermediate piers.

Besides the reasons already stated in objection to retaining walls of all descriptions, the single-arch bridge is also more expensive in first cost, although requiring less centering than the other. The wing walls of the bridge shown on the Plate are necessarily of great strength, to resist the pressure of the filling-in earth between them; and the same cubical quantity of brick-work may be so used as nearly, if not quite, to complete the three-arch bridge. In this case, if the bridge be in embankment, the whole of the filling-in earth-work incurs additional expense; and if in cutting, very little will be saved in earth-work in adopting the single-arch, while, on the other hand, the solid walls prevent the action of the air upon the slopes, which is found desirable for their hardening. And, moreover, the three-arch bridge facilitates vision along the line, and this is really essential to safety, especially over curves and in cuttings.

It must be observed that the economy in first cost of the three-arch certainly diminishes as the width of the bridge is increased, and we may conceive one so wide that the expense of the two additional arches should not be incurred, but in practice few such cases arise.

Figs. 1 to 7 represent a square bridge carrying an occupation road or way, 15 feet wide, over the railway at a point where the latter is about 5 feet below the original surface of the ground. Fig. 1 is a half elevation. Fig. 2, a half section, parallel with the face of the bridge. Fig. 3, a partial plan, taken beneath the string-course, level with the crown of the arches. Fig. 4 embraces a partial plan of one of the abutments and one of the intermediate piers. Figs. 5 and 6 are cross sections through the wing of the abutment, one taken near the arch, the other through the battering pilaster at the end of the wing. Fig. 7 is a half cross section through the crown of the centre arch. The arches are semi-ellipses; the centre one 30 feet span, with a rise of 8 feet 6 inches; the side arches 28 feet 3 inches span, and rise about 7 feet 6 inches.

Figs. 8 to 14 exhibit a single-arch bridge carrying an occupation road, 15 feet wide, obliquely over the railway, which is here nearly level with the original surface of the ground. Fig. 8 is a half section, parallel with the face of the bridge, and showing the breaks formed horizontally and vertically in the back of the wing walls. This section also shows the arch, abutment, and brick backing to the arch. The backing to both of the bridges shown on this Plate may, however, be more efficiently disposed by inclining the top surface of it so as to be tangential to the crown of the arch, and fall thence towards the extremity of the abutments or centre of the intermediate piers. It is evident that a more equal resistance is thus obtained to the thrust of the arch, and a better disposition effected for getting rid of water from the brick-work. Fig. 9 is an elevation of half of the bridge, and shows a pilaster carried up vertically 6 feet 9 inches in width. This pilaster serves for the imposts to break against on one side, and for the battering wing walls on the other. On the acute side of the arch, the abutment as high as the impost stone is brought out at right angles with the skew of the bridge, and on the obtuse side the abutment is similarly brought forward, and formed to show an equal splay with that on the acute side. Up to this height, therefore, the work presents no internal angles. Above the impost, however, the faces of the arch and spandrils are set back, and thus form uniform angles with the projection of the pilasters. The section, fig. 8, shows the footings of the counterfort, inclined at right angles with the battering back of it; and if this inclined bed be observed throughout the courses in the counterfort, its efficiency will be increased, as already observed regarding retaining walls. Fig. 10 is a half cross section of the bridge, showing a stone coping and string-course; the latter not carried through the entire thickness of the parapet. By this method, however, the bond of the work is injured, and although stone is saved, cannot be recommended. Fig. 11 shows a partial plan above the arch. Fig. 12, a partial plan above the foundations, showing the reduction of the wing walls. Fig. 13 is a half section of the arch and abutment, taken at right angles with the skew of the bridge, or as commonly called, 'on the square.' Fig. 14 shows a cross section through the wing wall near to the abutment.

Plate XXVIII. represents two substantial and handsome works on the London and Birmingham Railway; a bridge built over a river and sloping irregular valley, and one erected to carry the railway over a canal. Figs. 1 to 4 exhibit the former structure; figs. 5 to 10, the latter.

The bridge over the river consists of one main arch, 60 feet in span, and semicircular; and three semicircular arches, 17 feet span, on each side. The main arch has abutments each 14 feet thick. The bridge is 28 feet wide between the parapets, being adapted for a double line of rails to a gauge of 4 feet 8½ inches. Arches are turned between the spandrils to reduce the weight on the upper part of the arch, while a solid backing of brick-work supports the haunches. The piers between the side arches show a width of 8 feet on the face of the bridge, but are reduced to 2 feet 3 inches by three intermediate recesses in the width of the bridge. Fig. 1 is a half elevation. Fig. 2 is a half section, parallel with the face of the bridge. Fig. 3, a half plan over the parapets; and fig. 4, a half plan below springing. Brick inverts are turned between the side arches, and the levels of these and of the footings are determined by the original surface of the ground, which falls rapidly on one side towards the river. The entire height from the level of the water to that of the rails appears to be about 53 feet. A thick bed of concrete surmounts the arches and the intermediate backing. The slopes of the embankment are at 2 to 1, and start from broad benches on the original surface of the ground.

Figs. 5 to 10 represent the canal bridge. Fig. 5 is a half section, parallel with the face of the bridge; fig. 6, a half elevation. Fig. 7 is a half cross section through the crown of the arch, and with the retaining wall of the towing-path removed. Figs. 8 and 9 show a half plan, taken above the arch in fig. 8, and above the foundations in fig. 9; and fig. 10 represents the construction of the foundations of the abutments. In this case the railway is embanked about 16 feet above the original surface of the ground, and the entire site of one of the intended abutments presented a shifting mass, evidently incapable of sustaining permanently the load which the abutment would put upon it. An artificial foundation of a most complete character was therefore provided. First, four rows of piles were driven; fourteen piles in each row, and each pile about 20 feet long. The rows were 2 ft. 3 in. apart from centre to centre, and each pile was 2 ft. 4½ in. distant from the adjoining one in each row. Behind these four rows, seven other rows of piles, fourteen in each row, were driven, not vertically, but obliquely, as shown in fig. 5; and the tops of these were trimmed to a plane surface at right angles to their obliquity. A platform, partly horizontal and partly inclined, was then constructed upon the heads of these eleven rows of piles, thus: Over the pile-heads timber sleepers were fixed, corresponding in position with the rows of piles. Between these sleepers brick-work was built up to the level of the upper surface of the sleepers. Over the whole surface stout planking was then laid, and around the outer sides of the whole a row of sheet piling driven, with double walings bolted to it.

Upon the platform thus formed the abutment was built, consisting of stone in blocking courses, with brick-work above. The line of the extrados of the arch, which is a circular segment, 35 feet span and 6 feet rise, is continued down nearly to the ground, the materials of the entire abutment being thus disposed in a triangular form. The towing-path is retained by a dwarf wall, built upon piles. The design of this bridge is suited for a stone district, or one where that material may be cheaply procured.

In Plate XXIX. are exhibited the complete details of one of the interesting works on the London and Birmingham Railway, viz., the viaduct over the river Avon and its valley. Fig. 1 is a general sketch of the elevation of this structure. Fig. 2 is an enlarged elevation of one of the main and one of the side arches, with enough to show the design and dimensions of the intermediate piers, of which fig. 3 is a partial plan above the foundations. Fig. 4 is a half cross section through one of the piers; and fig. 5 is a section taken parallel with the face of the bridge through one of the end abutments, the three small arches adjoining, and the hollow pier which separates these from the main arches. This viaduct, of which the total length is about 350 feet, consists of nine semi-elliptical arches, 24 feet span, and 7 ft. 6 in. rise, and three semicircular arches at each end, of 10 feet span, faced entirely with stone. Each of the six end arches has a brick inverted arch between the piers above the foundations, which are carried along uniformly in a solid bed beneath these arches, with such steps and at such levels as the nature of the substratum required. The three middle arches have an inverted arch of brick-work, which forms an artificial channel for the river. This invert is faced at each end with a row of sheet piling, driven through the loam into a bed of strong gravel beneath. All the foundations which do not reach this gravel are built upon thick beds of concrete, and a layer of the same material covers the whole of the arches, forming a level bed for the gravel in which the sleepers of the railway are laid. The figures 4 and 5 show the iron down pipes by which the work is drained.

Plate XXX. shows the construction of iron girder bridges, and other works upon the London and Blackwall Railway. Figs. 1 to 9 refer to bridges for limited heights. The depth of girders in this case being limited to 14 inches, they are introduced in pairs, and are cast with projecting ribs on the sides, leaving a space for a wrought iron bar, curved in the manner of an arch, 3 inches by 2 inches, which bar abuts at the ends against suitable shoulders formed in the castings. The spaces between the girders are filled by cast iron arched plates, the concave sides of which form the soffit of the bridge. These plates have fillets on the sides, and are bolted through the girders, resting upon their lower tables. The girders are 28 feet in length, bearing 18 inches at each end upon the abutment walls. Fig. 1 is an outside elevation of one of the girders; fig. 2, an inner elevation; fig. 3, plan of two coupled girders; fig. 4, sectional through the covering plates at the crown, and against the fillet, showing half-lap joints. Figs. 5, 6, and 7 will explain the construction of the parapets, string-course, &c. The string-course and parapet standards are of cast iron, secured by lugs and bolts to the girders. The standards are formed with a groove on each side for receiving slate slabs, 2 inches thick, which form the panels of the parapet; and the whole is surmounted by a cast iron capping. Figs. 8 and 9 are sections through two pairs of the girders and the arched covering plates and joint.

Figs. 10 to 14 represent one of the 40-feet iron bridges erected upon the same railway. Cross timbers, 12 inches square, are fitted between the girders, and supported on their lower tables; and upon these timbers the chairs for the rails are spiked down. The girders are 43 feet long, bearing 18 inches on the walls at each end, and upon stone corbels built in the walls for a further length of about 2 feet. The cross timbers are placed 3 feet apart between centres on the line of railway; and at double this distance in the intermediate and side spaces. The face girders are parallel, moulded outside, and surmounted by an ornamental cast iron railing. The inner girders are curved on the top table, 2 feet deep at the centre, and 9 inches at the ends.

Figs. 15 to 18 exhibit the ordinary construction of the arches upon which the Blackwall Railway is supported. They are segments of circles, 30 feet span and 10 feet rise, with 3 ft. 6 in. piers, and 26 feet deep. The brick-work of the arch is 2½ bricks, or 1 ft. 10½ in. thick; stone string-course, and open iron railing. This example is thought worthy of record, showing a construction which has sufficed for a constant traffic of carriages and goods' trucks without locomotives.

On Plate XXXI. are shown the construction of an iron girder bridge, and of a timber foot bridge, both on the London and Birmingham Railway. Figs. 1 to 7 refer to the former structure; and figs. 8 to 14 refer to the latter. The iron girder bridge has two rows of arches, each 25 feet span and 2 ft. 6 in. rise. The outside girders are ornamental, but are aided by other girders immediately within, shown at fig. 3. The ordinary inner girders are shown at fig. 4. Fig. 2 is a cross section through the face and part of the length of the bridge, which is much extended in this direction, to carry a wide junction of roads above. Two wrought iron tie-rods, shown in this figure, extend throughout the whole length of the bridge. Fig. 5 shows a panel plate, fitted to cover the meeting of the two outside girders, which are bolted together over the intermediate pier, as seen in fig. 1.

For supporting a mere foot-traffic over a railway, the bridge shown in figs. 8 to 14 is an example of cheapness and efficiency. Two piers of masonry are built, one on each side of the line, and two timbers, 12″ × 9″, and about 40 feet long, are thrown across the piers, and bolted down upon them by bolts built in. Iron distance pieces, shown at figs. 8 and 9, are fixed between the timbers; 4-inch plank is laid upon them, and posts, braces, and top rail, properly connected with tenons and iron straps. Wooden steps are added on either side, with hand-rail and braces. The width of the bridge between the railings is 4 feet 6 inches.

Plate XXXII. shows the construction of the timber-arched bridges, constructed on the Newcastle and North Shields Railway, which have been described in the preceding part of this Section.

Plate XXXIII. exhibits three forms of timber bridges or viaducts, two of them being trussed, and the other formed of plain girders, constructed of baulks of timber bolted together. Figs. 1, 2, and 3 show one bay of a bridge built over the river Dove, and the contiguous valley, upon the line of the Birmingham and Derby Railway. Each truss consists of two half-timbers, each 7 by 14 inches, separated by a vertical space of 1 foot 7 inches. The span from centre to centre of the piles upon which the bridge is erected is 20 feet, which is divided into four equal spaces by cast iron struts or queen-posts, through each of which two iron rods pass. These rods pass also through the half-timbers, and have screwed nuts. The iron vertical struts are also formed with sockets to receive the ends of diagonal struts of timber, each 14 inches by 4 inches. Each bay consists of five of these trusses, which are supported upon transverse sills, 12 inches by 6 inches, resting upon the heads of the piles, there being five piles corresponding with the trusses in each row, forming the width of the bridge. The central space between the centres of the trusses is 6 feet, and the side spaces 4 feet 11 inches each. Diagonal braces, 4 inches square, are fixed between the trusses over the transverse sill. The flooring consists of 3-inch planks, laid transversely, and thus binding the five trusses together. The chairs to support the rails are bolted through the flooring. The parapet railings consist of wooden posts, 4 inches square, fixed 3 feet 4 inches apart, and bearing a wooden hand-rail. The posts are tenoned into cast iron shoes sunk in the flooring. Figs. 9, 10, and 11 show front and side views of the two forms of struts employed, and figs. 12 and 13 show the shoes for the railing posts.

Figs. 4, 5, and 6 represent one bay of a timber viaduct built over the valley of the Tame and Trent rivers, upon the same line of railway. The span is, in this case, 24 feet, but each bay consists of one central span of 21 feet, and one side span of 3 feet. The piles, of which a double number is thus required, are 9 inches square. The trussing consists of a tie-beam, 7 inches by 14 inches, and a top whole-timber, 14 inches square, halved at the ends. The projections of the central part have abutting struts, 7 by 14 inches, extending diagonally to the ends of the tie-beam into which they are tenoned. Over each pile a post, 7 by 14 inches, is fixed between the top timber and tie-beam, and two diagonal braces, each 14 inches by 4 inches, are crossed between them, over the side span of 3 feet.

There are five trusses in each bay, and they rest upon a transverse sill, 7 by 14 inches, supported upon the heads of the piles. Diagonal braces, 7 by 7 inches, are crossed between the trusses, over each row of piles, and a flooring of 3-inch planking is laid transversely. The ends of the flooring planks are stopped against a wooden nosing or string, upon which shoes are fixed to support a railing similar to that last described. Figs. 14, 15, 16, and 17 show side and top views of cast iron sockets, which were introduced at the junctions of the timbers of the trusses at the points A and B, as marked.

Figs. 7 and 8 show a transverse and longitudinal view of one bay of the timber viaduct which forms the Bricklayers' Arms branch of the South Eastern Railway. The span is 20 feet between the centres of the piles or posts. Each row of piles contains three, of which the central one only is vertical, the side ones being placed battering outwards at the bottom, at the inclination of 3 inches to a foot. The piles are 13 inches square, having a pair of waling pieces, each 12 by 6 inches, bolted against them, and struts, 9 inches by 9 inches, are fixed between the centre and side piles.

Each row of piling carries two transverse timbers, 13 inches square, one bolted upon the other, and these support six solid girders of timber, the two outer ones being 26 inches deep by 6 inches thick, to carry the ends of the flooring (which is 4 inches thick) and the railing, and the four intermediate girders, being of the same depth, but 13 inches thick, formed of two whole baulks, and being longitudinal bearers for the rails, which are flanged in the manner of the Great Western rails, and bolted to the flooring. By the side of the rails, wooden guard-rails, 6 inches square, are bolted down to prevent the wheels escaping from the rails.

Plate XXXIV. illustrates the construction of some of the timber bridges which have been constructed in America for the Utica and Syracuse Railway, the works upon which line are fully described in Mr. Weale's work on Railways.[19] Figs. 1 and 2 show the construction of bridges with 30-feet bays between centre of posts, which are 12 inches by 12 inches, and placed in rows, seven of them occupying the width of the bridge, which is 26 feet over. The trussing consists simply of half-timber girders, 14 inches by 7 inches, with two struts notched into the under side of the beam, which abut against and are bolted to the upright posts which constitute the piers: these are built upon masonry 2 feet in thickness, and diagonal braces, 12 inches by 3 inches, are bolted one on each side against the pier-posts. The flooring is $2\frac{1}{2}$ inches in thickness, bolted down to the half-timber girders. The railing consists of posts 5 inches square, fixed 3 feet 9 inches from centre to centre, and a hand-rail also 5 inches square. The girders are carried upon a cross sill, 12 inches square, notched down upon the head of the pier-posts.

Figs. 3 and 4 show an economical method of constructing abutments, partly

[19] 'Ensamples of Railway Making,' 1843.—Weale.

of masonry and partly of timber, and adapted for arches of large span; the figures exhibit one adapted for a span of 82 feet, built over the Oneida Creek: the foundation consists of white pine planking, 6 inches thick, laid longitudinally in the direction of the bridge, with a second layer laid across the first, and of the same thickness. Upon this foundation the masonry is erected, the height of which is about half that of the entire structure, and is built with faces battering 1 in 12, and the thickness at the top 7 feet, or about one-twelfth part of the span.

The timber framing which forms the upper part of the abutment consists of two rows of upright posts, 12 inches square, properly framed into a rectangular framing at top and bottom, made of timbers 12 inches square. There are seven posts in each row, or fourteen in each abutment: this framing is strengthened by braces, 9 inches by 3 inches, fixed diagonally in rows on the four sides of the framing, and also on the top and bottom of it, and the whole is put together with oak trenails, 1 inch diameter, and from 12 to 18 inches in length. The quantity of timber required for a framing of this construction and size will be about 450 cubic feet, or 9 loads.

Figs. 5, 6, 7, and 8 exhibit trusses adapted for spans of 30 and 40 feet, and employed upon the Utica and Syracuse Railway. Fig. 5 shows the elevation of the 40-feet truss, and fig. 6 a cross section, with a width of 22 feet between the trusses; this, however, would be insufficient for a double line of rails laid to the 4 feet 8½ inch gauge. The trusses are supported upon double rows of posts, 12 inches square; the rows being 2 feet apart, and the posts placed 4 feet apart between their centres in the row: each row of posts is capped by a cross sill, 12 inches square, notched down upon them. These carry the trussed beams, which are 15 inches deep, and formed of three thicknesses of four inches. Five intermediate timbers are also supported upon these sills, and serve, together with the trussed beams, to carry transverse timbers, each 12 inches by 7 inches, upon which the flooring is laid. The posts which form the abutments are cased externally with 3-inch oak plank, which is not shown in figs. 5 and 6. The quantity of timber in one 40-feet bay of a single-track bridge, 11 feet in the clear between the trusses, as given in detail by Mr. B. F. Isherwood,[20] amounts to 575 cubic feet, or 11½ loads, and the iron-work in bolts, washers, and bands, will be 568 lbs.

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[20] 'Description of the Mechanical Works on the Utica and Syracuse Railway,' published in the 'Ensamples of Railway Making.'

Figs. 7 and 8 show an elevation and half cross section of a 30-feet truss, supported upon abutments formed of single rows of piles framed into a lower sill and a cap above them, with inclined braces at the ends, having the same inclination as the embankment. Mr. Isherwood gives the quantity of timber for a single-track bridge of 30 feet span, 11 feet in the clear between the trusses, and of the construction shown in these figures, at 423 cubic feet, or about $8\frac{1}{2}$ loads, with 280 ℔s. of iron in bands and stirrups.

These trusses, as adopted on the Utica and Syracuse Railway, are boarded up, coped and painted, and the quantities of timber given above for each bridge include this boarding and coping-posts for rails, &c., complete.

On Plate XXXV., figs. 1 and 2 exhibit a timber bridge with three bays, each 40 feet span, adapted to carry a roadway over a railway; the abutments and piers are of masonry, and the roadway is partly suspended from the trusses. The width between the parapet railings is 12 feet; the trusses consist of a half-timber beam, 12 inches by 6 inches, with two queen-posts, 9 inches by 6 inches, carrying a tie-bar, 9 inches by 6 inches, and two diagonal struts, 12 inches by 6 inches. Diagonal braces, 6 inches by 6 inches, are fixed between the queen-posts. Over the abutments, upright posts, 6 inches by 9 inches, with the top rail, 6 inches square, complete the framing. A piece of timber, 9 inches by 9 inches, is built in the abutment, and projects 2 feet 3 inches on each side beyond its face, for the purpose of receiving the ends of struts, 4 inches square, to strengthen the posts of the framing. The roadway is formed with metalling, laid upon a longitudinal plank flooring, supported upon cross sills, 9 inches by 4 inches, and fixed about 2 feet 8 inches apart from centre to centre; the ends of these sills are notched down upon the half-timber girders. The whole of the framing is put together with wrought iron screwed bolts with nuts and washers, and the heads of the queen-posts and ends of struts and tie-beams are connected in iron sockets.

Figs. 3, 4, 5, and 6 show the method of constructing timber bridges which was patented in 1835 by Ithiel Town, an American engineer. The following is quoted from the description given of these bridges in Mr. Weale's work.[21]

"The form of this truss will be seen from the elevations in fig. 3, which are applicable to a double-truss bridge on Mr. Town's principle, there being a double truss on each side of the roadway. Each truss consists of a series of diagonal or truss braces inclined at an angle somewhat steeper than 45°, crossed by another series inclined at the same angle in an opposite direction, and of a horizontal string-piece on each side at top and bottom, the whole firmly secured by wooden trenails of hard wood, as shown in fig. 3. The height of the truss is usually about one-tenth or one-twelfth the span of the bridge or distance between the piers. The plan in fig. 5 shows the way in which the double trusses are put together with string-pieces between them, and the transverse section shows one end of a pier with the double truss erected on it, and part of the roof, extending across from one double truss to the other.

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[21] 'Bridges,' vol. ii. Supplement, p. lxxvi.

"There are two very distinct methods of building these bridges, according as the roadway is placed at the top of the trusses or on the level of the lower string-pieces. The first section in fig. 6 shows the first construction, and the second shows the roadway at the bottom, with the whole height of head-room, confined to the depth of the trusses by the beam which rests on them at the top. The first construction is that which will commonly be advisable when the span is not great, and when, consequently, it would be unnecessary to employ trusses of so great a height as 15 feet, which is about the minimum of head-room required for railways. In the case of wide roads also which are not railways, and where, consequently, suspension posts in the centre would be inadmissible, the first construction will be invariably necessary, however wide the span, unless additional strength be given to the floor beams.

"The second mode of construction has the advantage of enclosing the roadway both by a side and top covering or roof, and in both the designs exhibited in fig. 5 a wooden boarding, to protect the trusses from the weather, is shown on each side of the bridge.

"The trenails used for securing the truss-braces and string-pieces together, should be of white oak, or other hard wood, and in the large bridges of America are usually 2 inches in diameter. They should be exactly fitted to the augers used for boring the holes, so that when seasoned they may drive tight and make solid work. The patentee observes, that the trenails may be made different ways, but the best and most economical is to saw them out square from plank, with a circular saw, and then turn them with a small lathe, attached to some water or other machinery. They should be unseasoned, to be easily made, but must afterwards be well seasoned before driven into the work: they will season quickly, or may be kiln-dried. Tallow or oil, &c., may be rubbed on them to make them drive more easily, if necessary.

"In America, there are already many of these bridges, on a scale of magnitude truly gigantic. Among the most important of these is the one erected by the celebrated engineer Moncure Robinson, Esq., for carrying the Richmond and Petersburgh Railway across the falls of James River at Richmond. The length of this bridge across the river is 2900 feet, and the trusses are supported on eighteen granite piers, the distances between the piers varying from 130 to 153 feet. The piers are founded on the granite rock over which the rapids flow. Their height above the surface of the water is 40 feet, and they are carried up with a batter of 1 inch in 2 feet vertical, up to this height of 40 feet above the water, where their dimensions at top are 4 feet in breadth by 18 in length. The masonry consists of regular courses of stone, dressed on the beds and joints, but left rough or merely scabbled on the outside faces. The floor in this bridge is on the top of the truss frames, and the depth of these being 20 feet, the roadway is carried horizontally across the river at an elevation of 60 feet above the water. This bridge was completed in September, and its cost was about £24,200 sterling.

"In addition to this great work on Mr. Town's principle, executed by Mr. Moncure Robinson, may be mentioned another on the same principle, across the Susquehannah, 2200 feet in length, with spans of 220 feet; besides several others.

"These bridges may be constructed of any kind of timber, however soft, provided planks of about 27 feet in length can be sawed out of it. White pine, spruce, and poplar, have been extensively used in America; but oak is objected to on account of its tendency to spring or warp, if not well seasoned."

Plate XXXVI. shows two varieties of trussing adopted upon the Utica and Syracuse Railway for trusses of large span, and adapted for double-track lines: the abutments for these trusses are of masonry. The 86 or 88-feet span, shown in figs. 1 and 2, has a pair of timber arches bolted against the exterior of the truss, which descend below the stringers, and thrust against the stone abutments in recesses formed for them; they are also fastened to the end posts, which are produced downwards for that purpose. In casing up the bridge, the arches were cased separately, and moulded. The quantity of timber for a double-backed bridge of three trusses, and constructed as shown in figs. 1 and 2, will be, according to Mr. Isherwood, 2953 cubic feet, or about 59 loads; and the total weight of iron, in bolts, bands, &c., 4328 lbs.

Figs. 3 and 4 exhibit the bridge by which the railway is carried over the

Oneida Creek: the span is 84 feet. The following extracts from the specification for this work will sufficiently explain its construction. "The abutment from the top of masonry shall be carried up to the level of the bridge stringers by a trestle-work of wood, constructed as follows:

"Two parallel vertical frames shall be erected at a distance of 3 feet asunder; they shall be strongly braced and united at top and bottom by cross ties. Each frame shall consist of a sill and cap-piece, separated by a distance of 14 feet. The sill and cap-piece of each frame shall be united by seven vertical posts tenoned into them, and well trenailed. Upon the outside of the posts, braces shall be pinned. The cross ties which unite the frames at top and bottom shall be dovetailed 4 inches into the sills and cap-pieces.

"The posts shall be so disposed, that one pair shall be immediately beneath a bridge truss. The three pairs directly under the bridge trusses shall be stiffened by cross braces, pinned against either side. The timber to be of sound white pine.

"The superstructure of the bridge is to be composed of three parallel vertical trussed frames, placed upon the foundations at right angles, and separated from each other by distances of 11 feet. The trussed frames and the timbers to be firmly bolted together. The flooring beams are to be placed at right angles to the trussed frames. The joints of the arch-pieces to be in the line of radii to the arc. The string timbers to be spliced with three splicing bars to each joint; said splicing bars to be 11 feet long, pierced with holes, and fitted with spurs on the ends: one hole in each end of every bar is to be so placed that the bolt will pass through the adjacent post. A splicing timber, 5 inches by 18 inches, and of such length as will fill the space between the posts, shall be inserted between the stringers, and the bolts shall be screwed until all the timbers are forced into close contact.

"The floor is to be formed with sound 2½ inches thick white pine plank, laid edge to edge, and firmly spiked to the floor beams. The sides of the trussed frames are to be cased up with sound, well-seasoned white pine tully boards, planed, matched and nailed on vertically edge to edge in close contact. Furring pieces are to be interposed between the casing and truss frame. The trusses to be coped with sound white pine plank, projecting 2 inches over their sides: the upper surfaces of said plank to be properly bevelled for throwing off the water, and the under surfaces to be wrought with a groove."[22]

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[22] 'Description of the Mechanical Works on the Utica and Syracuse Railway,' published in the 'Ensamples of Railway Making.'

The figures on Plate XXXVII. show a variety of centres adapted for elliptical and segmental arches, and which have been adopted in the construction of several railway works. Figs. 1, 2, and 3, show the kind of centering and scaffold made use of in constructing the masonry of tunnels. Fig. 3 is a side view of one of the two framings upon which centres are supported. Fig. 4 shows a centering for an elliptical arch of 40 feet span, and is adapted for cases in which the abutments are very low, or an unusual height is required to be left clear while the work proceeds; but this form cannot be recommended except in cases where these conditions are imperative. The centerings shown in figs. 5 and 6 are also adapted for spans of 40 feet, and both also require intermediate supports the same as in fig. 4, between those at the extreme ends. Fig. 7 shows a centering for a span of 40 feet, but in which the width is not interrupted by having intermediate supports: an available height beneath the centering is still preserved, equal to that shown in fig. 6. Fig. 8 shows a centering for a 30-feet elliptical arch. Fig. 9 shows a centering for a 60-feet segmental arch, in which it was attempted to secure a high space for traffic beneath the work, without using any intermediate supports between the springing points of the centre. In this case, however, the construction was not found sufficient, and struts were obliged to be introduced in the position shown by the dotted lines, in order to prevent the centering from giving way.

In constructing bridges over cuttings it is sometimes practicable to dispense altogether with centerings. On the Birmingham and Gloucester Railway a bridge was built in this manner of blue lias limestone. The span is 60 feet, with a rise of 10 feet; the arch is composed of very small stones, from 3 to 5 inches thick, and squared to about 9 inches long and broad. "The material of the cutting where the bridge is situated consisted of weak slate and clay; consequently the mode of construction was subjected to a severe test. The abutments being completed to the springing height, the ground was cut away roughly to the form of the arch; seven rows of pegs were then inserted, with their upper ends correctly designing the proper curve; a line of planks, 3 inches thick, was laid transversely beside each row of pegs, and upon them were placed lines of battens on edge, gauged to the exact profile of the bridge; the earth was consolidated, and a flooring of battens laid over all, to form a true bed for the soffits to rest upon.

"From the absence of parallelism in the lias stones, their varying thickness, and the difficult adhesion to the mortar, it was deemed necessary to introduce seven transverse bonds of freestone, which imparted to the whole structure a tendency to settle in the lines of the radii of the arch, and also prevented any rent in the lias masonry from proceeding to a dangerous extent: these freestone bonds were firmly fastened with iron cramps. The face has a batter of 1 in 9, from the springing to the string-course, in order to counteract any tendency to bulge towards the faces, or in the line of the least resistance. The base was also extended, and the crown narrowed, which gave a concave form to the string-course. The whole arch being filled in with the full depth of stonework on each springing, and the bonds of freestone all placed, the lines of each between the second and third bonds were keyed up, and then those between the third and centre bond, which thus apparently formed the key-stone.

"The earth centre was removed by cutting a heading 4 feet 6 inches wide, directly beneath the key-stone, and then gradually excavating on either side uniformly towards the abutments, stopping at certain intervals to allow any settlement to take place.

"By proceeding thus, as successive portions of the arch were left to their own bearings, regular compression ensued, and a small portion only of the work was exposed to fracture from inequality of pressure: the rising of the haunches, which generally accompanies any undue depression of the crown, appeared by this method to be entirely avoided." [23]

The settlement of the arch did not exceed 2½ inches, and the experiment appears to have answered completely, having saved time, and also the expense of the usual wooden centre, beside which advantages, the bridge was ready when the cutting reached it.

In a bridge built over the Dublin and Drogheda Railway on the lattice principle, wrought iron has been introduced. This bridge is constructed over an excavation 36 feet deep. The span is 84 feet in the clear, and the two lattice beams are supported at each end on stone abutments built in the slopes.

These beams are 10 feet in depth, and are formed of two series of flat wrought iron bars, 2½ inches by ⅜ of an inch, crossing at an angle of 45°. At a height of 5 feet 6 inches above the lower edge, transverse bearers are fixed, and upon these the planking for the roadway was laid.

These bearers were formed of ¼-inch angle iron, 6 inches deep, and placed

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[23] Minutes of Proceedings of Institution of Civil Engineers, printed in 'Civil Engineer and Architect's Journal,' vol. iv. p. 394.

2 feet apart. The beams were cambered 12 inches in the centre. The total cost of the bridge, including the masonry of the abutments, was £510. A description of this bridge was presented to the Institution of Civil Engineers in 1844.

The Victoria viaduct, on the Durham Junction Railway, "consists of four large and six small arches: the river arch is of 160 feet span, the adjoining arch is only 144 feet, the next arch on either side is 100 feet, and the three land arches on each side 20 feet in span; the middle pier is 23 feet 9 inches, and the other large piers 21 feet 6 inches in width; the length of a pier is 54 feet from point to point, and above the springing of arches 31 feet in length. Each pier has three courses of footings, altogether 5 feet high; the piers are not solid, but built with cross walls up to the springing level; over the arches are introduced spandril and cross walls; the whole being flagged over to receive the road materials. The piers are grounded on the solid rock, but the south abutment, being over quicksand, required to have an artificial foundation of piles, sleepers, and 3-inch Memel planking, in two thicknesses; the piles are of Scotch fir, 10 inches diameter and 14 feet long, and driven 3 feet apart. The lowest part of the foundation is 40 feet below the ordinary flood level. The whole length of the bridge is 811 feet 9 inches; and the top width, including parapets, which are solid and 4½ feet high, 23 feet 3½ inches."—(Whishaw.)

The cost was £38,000. The quoins of the two larger arches are of Aberdeen granite; all the rest of the bridge is built of stone from Pensher Quarry, in the neighbourhood.

On the Great Western Railway there are four bridge works of considerable extent, viz., the Wharncliffe viaduct, over the Valley of the Brent,—the bridge over the Thames, at Maidenhead,—the Bath viaduct,—and the bridge over the Avon. The Wharncliffe viaduct is of brick-work, with stone imposts, cornices, and copings; it has eight elliptical arches, each 70 feet span and 19 feet rise, built in rings; they are 3 feet thick at the crown, and increase to nearly double this thickness at the haunches.

The piers are in hollow panels, and average 13 feet thick. The height from the ground to the springing is 40 feet 6 inches, from bottom foundation to top of parapet, 81 feet. The clear width between the parapet is 30 feet.

The Maidenhead bridge is built chiefly of brick-work, and consists of two elliptical arches over the river, each 128 feet span, with a rise of only 24 feet 3 inches; two arches adjoining these, each 21 feet span; and six end arches, three on each side, each of 28 feet span. The central pier is 30 feet thick. The principal arches are 63 inches thick at the crown, and 85 inches at the haunches.

The Bath viaduct consists of sixty-five segmental arches, varying in span from 19½ to 20½ feet, and built entirely of Bath stone. The arches are 3 feet thick at the springing, and 2 feet at the crown.

The bridge over the river Avon is constructed of timber framing on stone piers; it consists of two openings, each 89 feet wide, and rising 16 feet 9 inches.

A cast iron bridge, built for carrying the Birmingham and Gloucester Railway over the river Avon, is remarkable for the construction of the piers. The bridge consists of three segmental arches of cast iron, each 57 feet span and 5 feet 2 inches rise. The arches are "formed externally of cast iron plates or caissons, filled for the first 12 feet from the bottom with solid masonry or concrete, upon which is built hollow masonry to support the cap-plates, which carry eight pillars on each pier, with an entablature, to which are attached the ends of the arches, which, with the caps, pillars, and entablature, are of cast iron. The abutments at either end are of masonry.

"The caissons are, at the bottom, 41 feet 6 inches long, and 16 feet wide, with semicircular ends, tapering upwards for 12 feet on all sides to 34 feet 6 inches long, by 8 feet 6 inches wide, from whence they rise perpendicularly for the remaining 8 feet 9 inches. They are constructed of cast iron flanched plates, ¾ inch thick, screwed together by bolts, and the joints made with iron cement. The total weight of each caisson is about 28 tons.

"The bottom of the river at the site of each pier having been prepared by a scoop-dredger, worked from a platform erected upon piles, the lower row of plates for the caisson was put together, and suspended in the water by iron rods, while the other rows were added, gradually lowering the whole as the work proceeded, until the bottom rested on the bed of the river. A quantity of clay was then thrown round the outside, which formed a joint so impervious to water, that with two pumps, each of 5½ inches square, the caisson was emptied in six hours, and was afterwards kept dry by one pump, which was worked occasionally during the subsequent excavations withinside the caisson.

"The total cost of the bridge, including iron-work and painting, masonry, subsequent repairs to the walls, and superintendence during construction, was £10,192; and the weight of cast and wrought iron employed was about 520 tons."[24]

On the same railway a wooden lattice bridge, on the American principle, has been constructed over a cutting near Bredon. This bridge is 117 feet in span, 17½ feet wide in the clear, and about the same height.

The Manchester and Birmingham Railway is carried over Fairfield Street, at Manchester, by a bridge formed of six cast iron ribs, each of which extends to a length of 129 feet 6 inches, and has a versed sine of 12 feet. These ribs are carried in cast iron abutment sockets, built in masonry: from these the ribs spring at right angles with the direction of the railway; but the street beneath crosses at an angle of 24½°, and the span between the abutments, measured at right angles with the direction of the street, is only 53 feet 5 inches. The whole weight of iron in this arch is stated to be 540 tons.

The cast iron bridge which carries the London and Birmingham Railway over the Regent's Canal is 50 feet span, and adapted for four lines of rails. It consists of girders parallel at top and bottom, but having an arch cast in them with intermediate open spaces between this arch and the top and bottom lines. Each girder is cast in two pieces, bolted together, each 25 feet long, besides the length which bears within recesses formed in the abutments. Two of these girders are fixed parallel to each other, and about 3 feet apart. This pair of girders constitutes one rib, of which there are three, placed parallel, and about 28 feet apart between centres; there being two lines of railway between each two ribs. Below each of the outer ribs there are two horizontal tension rods, and below the middle rib there are four similar rods. These rods, which are of wrought iron, 3 inches in diameter, are secured at the ends of the girders in sockets with keys and gibs, and they have also intermediate couplings by which they may be tightened. Between the two girders which form each rib cross bracing frames of cast iron are fixed, at about 6 feet apart. From these frames vertical rods, 2¼ inches diameter, are suspended in sockets and held by keys. These suspension rods pass through sockets cast in the ends of cast iron girders, which they thus support, being retained by keys below; and upon these transverse girders the oak bearers for chairs and rails are fixed. Cast iron covering plates, of a lattice pattern, are fitted in between the rails. The two outside girders are ornamented with open bands or fillets of cast iron, bolted to the girders in lengths. Cast iron plates cover the spaces between the girders, in each rib, occupied by the bracing frames. Detailed engravings of this structure will be found in the 'Public Works of Great Britain.'[25] Two bridges of similar construction have been built at Leeds, one of which is 112, the other, 152 feet span.

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[24] Minutes of Proceedings of Institution of Civil Engineers. January, 1844.

In the course of railway making, many oblique or skew bridges have been built in an economical manner by using cast iron girders, as in that on the Manchester and Birmingham line just described. In these cases the abutments merely require recesses or notches to be formed in them, giving a square bearing for the abutment plates, so that these may bear with their entire rectangular surface. Many beautiful examples of oblique bridges of masonry may however be instanced among railway works. On the London and Birmingham line the railway is carried over the turnpike-road, at an angle of 32°, by an oblique bridge, built of bricks, with stone skew-backs, voussoirs, string-courses, and copings. The arch is 21 feet span on the square, and 39·627 feet on the oblique face. The acute angle of the voussoirs is cut off at right angles to the face of the arch, and the cutting is gradually diminished to the opposite or obtuse quoin, where it vanishes. Thus no angle less than a right angle is presented on the surface of any part of the work.

On the Croydon and on the Midland Counties Railways, brick bridges have been built in parallel sections of an arch which is square with the road or railway to be carried. On the latter railway a bridge of this kind is built over it, having these parallel ribs of brick-work about 4 feet broad on the square, elliptical in form, and 42 feet 6 inches span, with a rise of 11 feet. The plan of the abutments thus presents a series of notches or steps, from each of which one of the brick ribs springs. This construction, however, requires, in cases of great obliquity, either very thick arches or very narrow ribs of brick-work, unless intermediate spandrils are introduced to fill up the spaces between the soffit of one rib and the extrados of the adjoining one. Thus an extra expense, or an inferior bonding and strength, will be incurred.

A method has been adopted of forming oblique arches by building the central part of them as square arches, springing at right angles from the abutments, and filling in the ends left at the acute angle on either side with courses, the beds of which are worked as if for part of a true elliptical arch. This is believed by some to be a readier method of completing the work than by following uniformly through the arch the true spiral lines of which it should consist. Some bridges were constructed on the Bolton and Preston Railway in the compounded manner here referred to, and were described in a Paper read before the Institution of Civil Engineers in 1842.

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[25] Weale. London.

In the construction of brick or stone bridges for railways, much work may be saved by adopting (where allowed) wooden posts and rails instead of solid parapets. The parapet piers may in this case be built out upon corbels beyond the face of the bridge, and thus the same clear width obtained between parapets, and from 1 to 2 feet of brick-work in thickness be saved throughout the work. This method has been adopted in some designs for brick bridges for railways lately prepared by the writer. A tabulated abstract of the quantities in a few of these may be introduced, in order to show the increasing ratio in which the quantities are augmented by additional height of structure.

TABLE A.

Brick bridges over cuttings; 30 feet wide clear between railings; arches 30 feet span, 1 foot 6 inches thick.

Depth of cutting, or height of bridge. Feet.	Excavation. Cubic yards.	Concrete. Cubic yards.	Brick-work. Cubic yards.	Stone-work. Cubic feet.	Wood-work. Cubic feet.
14	98	60	330	402	42
30	112	100	530	465	124
60	915	180	1730	924	280

These are all of similar design: the comparatively great quantity of stone in the 14-feet is employed in imposts of that material, which are not intended in the others. All the designs are of the plainest character, and all the sections are of studied economy in quantity of material.

The following Table, compiled from other designs of the same series, will illustrate not only the similar increasing ratio for bridges in embankments, but also the greater quantity of material required for bridges in embankments than for those in cuttings.

TABLE B.

Brick bridges in embankments; 30 feet wide clear between railings; arches 30 feet span, 1 foot 10½ inches thick.

Height of embankment or bridge. Feet.	Excavation. Cubic yards.	Concrete. Cubic yards.	Brick-work. Cubic yards.	Stone-work. Cubic feet.
19	158	80	405	478
30	278	140	545	395
50	314	157	2290	682

The comparatively larger quantity of stone stated for the 19-feet bridge was required for coping to wing walls, while the other bridges are without such walls, and cut into the bank, which is trimmed around them. A tunnel bridge, with an arch 2′ 3″ thick, in a 40-feet embankment (slopes 1½ to 1), contains 295 yards of excavation, 148 yards of concrete, 751 yards of brick-work, and 653 feet of stone-work.

An approximation to the ratio in which the quantities increase for oblique bridges, and for various angles of obliquity, may be derived from the following abstract of quantities for other designs in the same series.

TABLE C.

Brick bridges in embankments, at various angles of obliquity; 30 feet wide clear between railings; arches 30 feet span, 1 foot 10½ inches thick.

Height of embankment or bridge. Feet.	Angle of obliquity.	Brick-work. Cubic yards.	Stone-work. Cubic feet.
30	80°	1122	414
,,	60°	1198	860
40	80°	2000	766
,,	60°	2394	792
,,	40°	2598	1017
,,	30°	3336	1227
50	80°	2348	727
50	60°	2616	1184

All the arches, where height admitted, are semicircular, and of 30 feet span. The piers are in all cases, where practicable, lightened by arched openings in the width of the bridge. Two courses of footings are provided for. The arches in most cases spring plain from the pier, without stone or other imposts projecting either on the side or face of the pier.

TUNNELS.—Among the costly and laborious works of a railway, its tunnels occupy the first place. Like mining, and all other subterranean operations, the construction of a tunnel can be but little aided by mechanical appliances; it chiefly requires hard manual labour, exercised under circumstances which do not admit of that thorough superintendence which promotes economy, and, moreover, liable to unforeseen interruptions, of surmounting which neither the manner nor the expense can be predetermined. Thus the Kilsby tunnel, on the London and Birmingham Railway, was estimated to cost about £40 per yard lineal; whereas its actual cost was £130 for the same length, owing to its intersecting a quicksand, which the trial borings had escaped. Thus a vast expense was necessarily incurred in setting up and working pumping machinery in order to dry the sand. The pumps brought up nearly 2000 gallons per minute, and were working during a period of nine months. The quicksand extended over a length of about 450 yards of the tunnel. The Box tunnel, on the Great Western Railway, excavated through oolite rock, and being lined with masonry only through a portion of its length, cost upwards of £100 per lineal yard. The Bletchingley tunnel, on the South Eastern Railway, cost £72 per lineal yard; and the Saltwood tunnel, on the same line of railway, cost £118 per lineal yard. This greater cost in the latter work was occasioned by the great body of water in the lower green sand which the tunnel intersects.[26]

The method of proceeding with tunnelling depends mainly upon the kind of material to be excavated. This having been generally ascertained by borings and trial shafts, the work is commenced by sinking the working shafts, which must be sufficiently capacious to admit readily of lowering men and materials, raising the material excavated, fixing pumps, and also for starting the heading of the intended tunnel when the required depth is reached. Besides the trial and working shafts, air-shafts are sunk for the purpose of effecting ventilation in the works below.

The working shafts are made cylindrical, and from 8 to 10 feet internal diameter: 9 feet is a favourite dimension. They are of brick-work, usually 9 inches thick, and carried up 8 or 10 feet above the surface of the ground, finished with stone coping. These, and all other shafts, rest upon curbs of cast iron, fitted into the crown of the tunnel, and forming a level base for the shaft. The air-shafts are of similar thickness and form, but usually about 3 feet internal diameter. They should not be allowed to be sunk near to the working shaft, or at a less distance than 50 yards from it. All the shafts are, of course, sunk on the centre line of the intended tunnel. In the Bletchingley tunnel, the trial shafts, 6 feet diameter in the clear, 9 inches thick, and 35½ yards deep, cost £6 per yard down through the Weald clay. A similar shaft in the Saltwood tunnel, 25 yards deep, cost £4. 15*s.* per yard down, in the lower green sand. Horse-gins are usually employed in raising and lowering the materials, &c., and also in drawing the water up the shafts, unless large pumps be used and worked by steam power. Mr. Simms calculated the expense of horse labour thus exercised at 2¾*d.* per ton lifted 100 feet high, and including the boy to drive the horse.

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[26] The description given of the construction and cost of the two tunnels on the South Eastern Railway, by Mr. Simms, in his treatise on 'Practical Tunnelling,' is most complete and instructive.

The number of working shafts will depend chiefly upon the rate of speed with which the work is required to be accomplished. With plenty of men, horses, materials, and plant, the work is much facilitated by sinking extra shafts, and will usually well repay their cost. The Watford tunnel, 75 chains in length, on the London and Birmingham Railway, was specified to be worked with six shafts, not less than 8 feet diameter within the brick-work, and 9 inches thick; the brick-work moulded to fit the circumference of the shaft, and laid in two half-brick rings; an air-shaft at a distance of 50 yards on each side of each working shaft, and not less than 3 feet 6 inches diameter inside; the arch and side walls of the tunnel, usually two bricks thick, and the invert, one and a half-brick, except in places where the stratum passed through seemed to require an increased, or admit a diminished thickness. The form of the top of the tunnel is nearly semicircular, supported by curved side walls standing on stone footings or skew backs, which rest on the invert forming the base of the tunnel. The ends of the tunnel are formed with wing walls. The brick-work at the ends of the tunnel is bound by wrought iron rods 100 feet long, secured at each end in a cast iron rim or plate built into the brick-work.

The Northchurch tunnel, which is 16 chains in length, on the same line of railway, was worked with two shafts, each 9 feet diameter. In the construction of this tunnel, a heading was driven, 4 feet wide, and 5 feet high, throughout the entire length of the tunnel, and between two shafts sunk for this purpose, one near each end of it. It was specified that this heading should be driven through before any part of the tunnel was commenced, and supported and kept open during the execution of the entire work by sufficient timbering.

In commencing the works of the Saltwood tunnel, already referred to, great difficulty was encountered from the great quantity of water in the lower green sand which the tunnel intersects. The course adopted was to make a heading or adit quite through the hill on a level with the bottom of the tunnel, in which the water was collected and drained off. The size of this, and also of the Bletchingley tunnel, is 24 feet wide at the broadest part, 30 feet including the side-walls; 25 feet high in the clear, 30 feet including the invert and top arch, or 21 feet clear above level of rails. The brick-work in top arch and walls varied from two and a half to four bricks in thickness; the invert three bricks thick.

When water occurs in the sinking of the shafts or the building of the tunnel, the back of the brick-work should be well lined with puddle, and Roman or metallic cement substituted for mortar. The whole of the Kilsby tunnel, on the London and Birmingham Railway, was built in either Roman or metallic cement, and the thickness of the brick-work is chiefly 27 inches. This tunnel is about 2423 yards long, and its length is divided by two ventilating shafts, cylindrical, and 60 feet in diameter. These shafts are 3 feet thick in brick-work, laid in Roman cement throughout. They intersect the line of the tunnel, and form curved recesses by that portion of their circumference which extends beyond the width of the tunnel on either side. These shafts were built from the top downwards, by excavating for small portions at a time, from 6 to 12 feet in length, and 10 feet deep.

The Box tunnel, on the Great Western Railway, intersects oolite rock, forest marble, and lias marl, with fullers' earth. Eleven principal shafts, generally 25 feet in diameter, and four intermediate shafts, 12 feet 6 inches, were sunk for the purpose of carrying on the works of this tunnel, the entire length of which is 3123 yards, or a little more than 1¾ miles. The section of the tunnel is designed to be 27 feet 6 inches wide at springing of invert, and 30 feet wide at a height of 7 feet 3 inches above this; clear height above rails 25 feet. As a great portion of the tunnel is constructed by mere excavation, and without masonry, these dimensions are, in some cases, departed from, in order to clear away loose portions of the stone and secure solid surfaces. Where brick-work is used, the sides are seven half-brick rings in thickness, the arch six, and the invert four. During the construction, the constant flow of water into the works from the numerous fissures in the rock, compelled pumping on a most expensive scale to be adopted. From November, 1837, to July, 1838, the works were suspended, the water having gained so completely over the steam pump then employed, that the portion of the tunnel then completed was filled with water, as also a height of 56 feet in the shafts. A second pump, worked by a steam engine of 50 horse-power, was applied, and enabled the works to be resumed.

When the working shafts are sunk sufficiently deep, a narrow heading is excavated, from 6 to 12 feet in length, 3 or 4 feet wide, and high enough for a man to work in. The top of this heading should be so much above the intended soffit of the tunnel-arch as to admit the thickness of the brick-work, besides the bars of timber and boarding by which the roof of the heading is supported, and also allowing several inches for the settlement of the timber, which always occurs as the excavation is proceeded with, and before the brick-work can be got in.

This allowance is of the utmost importance, as without it the brick-work will, when the settlement occurs, be forced down, and can only be raised to its proper level by removing the superincumbent earth piecemeal, and at great cost. The bars, and poling and packing boards, are introduced in the most convenient manner, according to the nature of soil excavated and the degree in which it requires support, or may be safely left unsupported.

The heading is extended on either side by cutting first narrow gaps horizontally, or rather dipping downwards in directions following the intended form of the tunnel-arch. Into these gaps crown bars are laid lengthwise, and supported upon props; and poling boards are put in between them, to retain the earth at the sides of the excavation, when extended. When the heading has thus been widened by excavating right and left, and a sufficient length cleared, the centerings are fixed, and the brick-work is commenced. As this proceeds the earth is carefully rammed behind it, and all vacancies filled up, to prevent any subsequent settlement of the surrounding earth upon it. The crown bars which were inserted in the heading, and always during the excavations, are not always removed. If they can be drawn forward as the heading advances, without disturbing the adjacent ground, and the spaces filled up with broken stone, or other suitable material, no objection can arise; but otherwise they should be allowed to remain, and be built in. The whole of the operations require carefully regulating, so that none of them shall advance too rapidly for those which follow. The contractors are therefore usually restricted to carry the excavation not more than 6 or 8 feet in advance of the brick-work, or less, if so directed by the engineer, should any change occur in the strata which he thinks may require such precaution. When the faces of two contiguous excavations approach within about 50 yards of each other, a heading should be driven quite through the intervening ground, and the workings joined before the whole excavation and brick-work are proceeded with.

Experience has proved that the *quality* of the bricks used in tunnel-work is of the utmost importance. If these contain lime on which the weather operates injuriously, the face of the work soon decays, and requires extensive repair or restoration. This was the case with the Beechwood tunnel on the London and Birmingham Railway, which in less than three years was considered to be in an unsafe condition, owing to this cause. The remedy adopted was of the most complete character; it consisted in an entirely new lining of brick-work, 9 inches thick. This tunnel is about 302 yards long, and passes through strata consisting of alternate layers of rock and marl, abounding with springs of water. By judicious arrangement, the lining was completed in forty days. The traffic being diverted to one of the two lines of rails which are laid in the tunnel, and a hoarding erected along the centre, the casing was carried up on one side to the height of 4 ft. 6 in. above the springing. At this point a course of York paving, 4½ inches thick, was bonded into the original work, and the new work was securely attached beneath it with wedges of iron; half-brick toothings were also inserted in chases cut 2 ft. 3 in. apart in the original work. The traffic was then turned into the line on the side thus cased, and the other wall was similarly treated. Bearers were then fixed 6 feet apart over head, and a close flooring laid upon them. Upon each bearer a pair of ribs were raised, and keyed stays and laggings were fixed, and the brick-work, in English bond, brought up on each side simultaneously, leaving a central space 2 ft. 3 in. wide at the crown. A moveable centre of this length was used to close in this space with two half-brick rings. Vertical chases, 4½ inches square, besides those cut for the toothings, were made in the face of the old walls previous to lining. These formed permanent drains, terminating in the culvert beneath the centre of the tunnel.

SECTION IV.

PERMANENT WAY AND CONSTRUCTION.

Under this Section it is proposed to give a general notice of those works which may be considered as constituting properly the railway.

Supposing the level for the intended line to be obtained as far as the height of embankments, the depth of cuttings, and the upper surface of bridges or viaducts under the railway, are concerned, the works will have attained what is called the formation level, and be ready for the construction of the Permanent Way. This comprehends a surface covering of gravel, cinders, or other similar ballasting, in which the sleepers are to be embedded. The sleepers, according as they are laid transversely to the direction of the railway or longitudinally with it, will support chairs, in which the rails will be carried, or will have the rails themselves bolted down at once upon them. This part of the work includes also the contrivances by which a communication is made between one line of rail and another, for the passage of engines and carriages: these contrivances consist of crossings and turn-plates.

For the ballasting, which should usually be from 18 to 24 inches in thickness, several materials may be used, according to the facility of obtaining them in the neighbourhood of the works. Loam may be used for this purpose, but is not so good as other materials. On the Aylesbury Railway a mixture of chalk and flints is used with much success.

The ballasting, 22 inches thick, employed on the Birmingham and Gloucester Railway, and which chiefly intersects strata of marl and lias clay, is of several kinds, viz., burnt clay, burnt marl, rock marl, gravel, sandstone, cinders, and broken lias and oolite stone. On the Bolton and Leigh and Clarence Railways the ballast is entirely of small coal, which answers extremely well. On the Chester and Birkenhead, Chester and Crewe, and other lines, a mixture of sand and broken stone has been employed. On many of the English railways, also on the Dublin and Kingstown, the ballasting consists of gravel and broken limestone, which makes a very superior and binding material. In other cases gravel alone is used, also a mixture of gravel and sand; broken stone alone has been sometimes employed, but is found to be somewhat deficient in the property of binding. Gravel and loamy sand have been used, not in the mixed state, but in two separate layers, the sand upon the gravel. On the London and

Birmingham, and also on many of the Belgian railways, this plan has been adopted with success. On the North Union Railway the ballasting consists of sand, with an upper layer of broken stone, 4 inches in thickness. On the Dublin and Drogheda Railway, as stone was readily procured, the whole surface of the line was pitched transversely with thin stones; upon this a good bed of broken stone was laid for ballast. A similar plan was adopted by Mr. Telford on the Holyhead road.

The foundations for the permanent way are now almost exclusively formed of timber. Originally blocks of stone were used for this purpose: two holes were drilled upon the upper surface of each block to receive wooden pins or trenails; and the cast iron chairs to support the rails were secured by iron spikes driven into these pins. The blocks of stone were from 21 to 24 inches square, and from 10 to 14 inches in thickness. They were embedded in the ballasting, sometimes square with the railway, and at other times diagonally to it. Many objections were experienced against the use of these blocks. Thus,—they offered no security for preserving the gauge of the line: the tendency of the weight passing over the rails being of course to thrust them asunder, the stone blocks yielded to this, except as far as their own weight and the rigidity of the rails themselves offered a resistance. Besides this, it was found that the excessive weight of the blocks disturbed the stability of the bridges and other constructed works. For these reasons timber was selected as a substitute, and has been since used mainly in two ways,—either as cross sleepers, each being wide enough to support the pair of chairs which determine the gauge of the line,—or in the form of longitudinal timbers, to which a rail formed with bottom flanches may be bolted without chairs; these longitudinal timbers being connected by cross ties, halved or dovetailed into the longitudinal timbers. For the cross sleepers, which are required from 7 to 9 feet in length for the 4·8½-feet gauge, half-round logs of beech, Scotch fir, or larch, are usually found the most convenient. They should be cut from timber averaging 9 to 11 inches in diameter. Figs. 8, 9, 10, and 11, Plate XXXVIII., show the two forms of construction hereinbefore pointed out, viz., the cross sleepers with chairs, and the longitudinal timbers without them. The latter system, having been selected for its superior stiffness by Mr. Brunel, as being peculiarly applicable to his 7-feet gauge, has become somewhat identified with the 'wide gauge,' but is not by any means peculiar to it, being applied on narrow-gauge lines with chairs and without them. Fig. 8 is a plan of a portion of a double line of railway laid upon cross sleepers, in which *a a* are the rails, *b b* are the chairs, and *c c* the cross sleepers. Fig. 9 is a longitudinal section, showing sections of the sleepers; the four marked *c* are represented as they have been commonly used, viz., with the cut or flat surface of the timber downwards, and the level space to receive the chairs being adzed upon the upper surface. It has been supposed that by thus placing the sleepers a wide and level bearing has been secured for them. On the South Eastern Railway, however, Mr. Cubitt has introduced an arrangement shown in the three sections marked *d*, *d*, *d*, fig. 9. These sleepers are of Baltic fir, cut from square baulks, divided diagonally into four triangular sleepers, and laid with the right angle downwards. These are sometimes contrasted with half-baulks, which present no more bearing surface for the chairs than do these triangular or quarter-baulk sleepers, and yet contain twice the quantity of timber. This comparison is however evidently inapplicable, unless square timber be proposed, which is much more expensive, and less readily attainable, than the rough logs commonly used for cross sleepers. It is said that the triangular sleepers offer advantages in the facility of packing, as the ballast can be consolidated by ramming, without lifting the sleeper or digging around it; and also the apparent disadvantage of its tendency to act as a wedge is denied, on the ground that the inclination of 90° exceeds the limits within which the principle of the wedge obtains. The evident advantage of not requiring to be adzed for the chairs, has been relinquished by Mr. Cubitt, who, for greater exactness, caused two places to be planed on his sleepers for the chairs to bed upon.

The distances at which the cross sleepers are placed apart must be an aliquot part of the lengths of which the rails are made; but this distance cannot exceed 3 feet 9 inches without requiring a much heavier and more expensive section of rail than will be sufficient if an extra sleeper be supplied for each 15 feet length of rail, by which the distance apart will be reduced to 3 feet. In some cases a distance of 2 feet 6 inches is adopted, and indeed the greater economy of frequent sleepers with light rails and small chairs, and the greater steadiness and equality of motion given to the carriages by this arrangement, are now generally admitted.

The construction exhibited in figs. 10 and 11 is that now adopted on the Great Western Railway, and other lines connected with it. A different arrangement was tried upon this line: instead of cross ties, lying flush with the longitudinal timbers, cross beams or transoms of pine timber, 13 inches by

6 inches, were framed beneath the longitudinal sleepers. These transoms were placed at 15 feet apart, and were of sufficient length to embrace the two lines of railway, or the four longitudinal sleepers. Piles of beech timber, about 9 inches in diameter, and 8 feet in length, were driven down into the ground adjoining the transoms, and bolted to them. This plan has been abandoned in favour of that shown on figs. 9, 10, and 11. The longitudinal timbers are 12 by 6 inches, and the cross timbers 6 by 4 inches.

Figs. 1 to 7 represent the sections of seven varieties of rails: of these, that shown in fig. 1, which is known as a double T rail, has been used, with difference of dimensions, on many railways, laid to the 4 feet 8½ inches, or Birmingham gauge. The figure shows exactly that adopted on the Aylesbury Railway.

Fig. 2 shows one of the sections used on the Birmingham and Gloucester Railway, and may be taken as an example of another class, having the bottom web extended laterally and bevelled off at the sides. The entire section is much less in depth than the double T rail.

Fig. 3 is an example of the Great Western, or 'bridge-rail,' adapted for longitudinal sleepers, and bolted to them by bolts passing through its lower webs or flanches.

Fig. 4 shows one of the sections employed upon the Liverpool and Manchester Railway, having the top surface inclined and curved, with a view to correspond with the lip and conical tire of the wheel.

Fig. 5 is a section of the rail used on the London and Croydon Railway, and presents a combination of the T rail with the broad base of the bridge-rail. Like the latter, this rail is adapted to be bolted down upon longitudinal sleepers.

Fig. 6 shows the section of rail employed upon the Brandling Junction Railway, and is similar to that used on the Newcastle and Carlisle, and other lines.

Fig. 7 represents the single T section which has been used on several lines. The figure shows that selected for the Chester and Birkenhead Railway.

The sections 1, 2, 4, and 6, may be secured in the chairs which support them by wooden keys, wedges, or other means; 3 and 4 are, as already described, secured by bolts to longitudinal timbers; and fig. 7 requires a notch on the side, into which a ball key or other projection may be driven from the chair to prevent the rail rising.

Plate XXXIX. contains representations of the chairs which have been chiefly used and approved of for supporting the rails.

Figs. 1, 2, 3, and 4 exhibit the chairs introduced by Mr. G. Stephenson, and which are especially adapted for the single **T** rail.

Fig. 1 is a section, and fig. 2 a plan, of one of the intermediate chairs. The novelty in this chair consists in the mode in which the rail is retained in its place, and prevented from rising. The rails are rolled with an angular notch along one side of them. The chair is formed with a cylindrical hole through one of the cheeks, and at such a height that will correspond with the position of the notch in the rail when supported in the chair. Through this hole a small iron ball is introduced; a split key is then driven through a hole in the cheek, which also crosses the groove in which the ball is placed: the ball is thus forced into the notch on the rail, and by this contrivance the latter is effectually confined in its position vertically, and yet permitted to move longitudinally when any alteration takes place in the length of the rail or the position of the chair.

Figs. 3 and 4 show a section and plan of one of the joint chairs, in which the ball apparatus is provided on each side of the chair, so as to act against the two rails. The main web of each rail is turned off at the ends at an angle with its length, so that the webs of each two contiguous rails may be lapped against each other without interrupting the uniform direction of their top tables, which are notched out to meet over the lap. The joint chairs, as will be seen by fig. 4, are placed obliquely to the line of railway.

Fig. 5 shows a section of a wrought iron rail and chair which has been used in America, and is described in the 'Civil Engineer and Architect's Journal.'[27] In this case B is the wrought iron chair, which is simply a rectangular piece of metal, notched on the upper surface to fit the bottom flanch of the rail, and having two bolt-holes formed in it. C C are wrought iron clamping pieces, formed at one end to fit upon the flanch and against the web of the rail. Each of these clamping pieces has a bolt-hole through it, so that when put together, in the manner represented in fig. 5, the sleeper, chair, rail, and clamps, are securely connected by two screwed bolts and nuts.

Fig. 6 shows the ordinary chair used on the London and Birmingham, and other lines, and is one of the simplest and most efficacious designs to be used with the double **T** rails. The space for the rail in this chair is straight on one side, but curved inwards on the other. Into this curved recess the lower flanch of the rail enters; the space then left between the straight cheek of the chair and the other side of the web of the rail is occupied by a wooden key or wedge, which is driven in until the rail becomes firm in the chair. So long as this key retains its place, the rail evidently cannot move sideways so that its lower flanch should escape from its recess in the chair, while the key itself is prevented from starting upwards by the projection of the top flanch of the rail. After dry weather, if the keys shrink so as to become loosened, they are readily replaced by a blow from the mallet. This defect is, however, obviated in a great degree by previously compressing the keys. This has been very successfully done on the South Eastern Railway, under the patent process of Messrs. Ransom and May, a description of which may be usefully quoted from the Minutes of Proceedings of the Institution of Civil Engineers, in March, 1842.[28]

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[27] Vol. i. page 169.

"Mr. May explained that the peculiarity of the system consisted in the fibre of the timber being compressed equally from the circumference to the centre.

"The pieces of wood for the wedges were cut out with parallel sides, and forced by hydraulic presses into tapering moulds: whilst in those moulds they were subjected to the action of heat, applied through the medium of low-pressure steam, and after being allowed to cool they were forced out of the moulds, and so long as they were kept dry would retain their form; but as the operation simply contracted the dimensions of the sap-vessels, without crushing the fibre, the power of capillary attraction was not destroyed, and when driven into the chair, and exposed to moisture, they swelled so as to remain perfectly tight. There was this difference between wedges so compressed and all others,—that a true wedge was formed from a piece of wood cut parallel on all sides, whilst all former modes that he was acquainted with produced not wedges, but parallel pieces.

"The diminution of the bulk of the trenails by the process is from 100 to 63, and of the wedge from 100 to 80. It is found that the wood does not swell until it is placed in a damp situation, as in the sleepers. Even the most solid wood, such as African teak, can be compressed without sustaining injury. Perfectly seasoned timber will not shrink after the process. One of the principal advantages of the compressed trenails is the firmness with which they hold into the sleeper. Around the iron spikes generally used, a sheath of rust is formed by the damp sleeper; the shaking of the carriages tends to draw them upwards, and the elasticity of the fibre around the hole in the sleeper being impaired, it is of no use to drive them down again in the same place, and the chairs eventually become loose."

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[28] Printed in the 'Civil Engineer and Architect's Journal,' vol. v. page 200.

The trenails of oak here referred to were used to fasten the chairs down upon the sleepers: on the Hull and Selby Railway also round trenails were used for the same purpose, being made of a proper size to fit the hole in the chair when driven in, and having a square head left on them, by which the chair was held down. The method of compressing trenails and wedges adopted previously to that used on the South-Eastern Railway, was by driving them through steel rings or moulds, either by blows with heavy mallets, or by one blow of the piston of a press.

Figs. 7 and 8 show a chair of somewhat complicated character, invented by Mr. G. W. Buck. The objects which Mr. Buck had in view in designing these chairs are explained by himself as follows:—"However strong the rail may be, a certain amount of deflection between the points of support must result from the gravity of the passing load; therefore, in order that no motion may be communicated to the chair, (which is essential to the maintenance of the road in good order,) the connection between the rail and chair must be such as to allow of the libratory motion arising from deflection, the rail being, nevertheless, firmly fixed upon its seat, incapable of rising therefrom, and prevented from lateral movement: at the same time it should be free to move longitudinally, as much as the expansion and contraction of its length from variation of temperature may demand. All these ends are attained by having the chairs constructed as shown in the Plate."[29]

The chair shown in figs. 7 and 8 is a joint or double chair, to which, however, the intermediate or single chair is exactly similar. The seat for the rail in the chair is convex, being $\frac{3}{16}$ths of an inch higher at D than at E, E, for the purpose of permitting the libratory motion of the rail caused at the moment of the load passing over it. This form, however, is not peculiar to the chair now under notice. That side of the chair which is next to the flanches of the wheels has contact with the rail at only two points, A and B. On the outer side of the chair the rail is confined to its place by a cast iron chock, F, made in a spheroidal form, and touching in a point only at C, about midway between A and B: this chock has a step or foot, G, resting on the seat of the chair, with a fillet, I, fitted into a corresponding groove. A wrought iron key, H, is placed in a mortise, partly in the chock and partly in the chair: thus the chock is wedged against the rail.

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[29] 'Public Works of Great Britain,' page 46. 1838. J. Weale.

Figs. 9 to 13 show the chairs used upon the South Eastern Railway. They are designed with a view to combine lightness with strength, and cast with inclined cavities for the rails, so as to secure the inward inclination of the rails, which it is thought desirable to preserve, in order to resist the thrust of the conical tires of the wheels. In the figures *a a* are the compressed wedges, and *b b* show the heads of the trenails, the mode of compressing which has been already described. Fig. 9 is an elevation of the chair; fig. 10 is an end view, and fig. 12 a plan of a joint chair; and figs. 11 and 13 an end view and plan of an intermediate chair: in fig. 13 the wedge *a* is supposed to be removed.

Figs. 14 and 15 show a form of chair adapted to single T rails, which was formerly adopted on several railways, and may be considered as a less elegant attempt to accomplish the object aimed at in Mr. Stephenson's chair, before described. In this case a cylindrical iron pin was placed in the groove *a*, having its front end bevelled off to correspond with the notch in the rail, and kept in its place by a split key, driven through it and through the chair at *b*.

Figs. 16 and 17 represent a kind of chair used on the Hull and Selby Railway: for this chair two compressed keys of oak, each 7 inches in length, are used, and the chair is held down by four spikes or bolts. This form of rail and chair is evidently adapted either for longitudinal or transverse sleepers, and on the Hull and Selby Railway both these modes of construction are adopted. With the longitudinal bearers, a lighter rail and chair are used than with the transverse bearers. In the former case the rails weigh 55 ℔s., being $2\frac{3}{4}$ inches deep, and the latter 63 ℔s. per lineal yard, being $3\frac{3}{4}$ inches in depth. The chairs are $2\frac{1}{2}$ inches and $3\frac{3}{4}$ inches deep for each system respectively.

Figs. 18 and 19 show chairs with hollow metal keys or pins, patented by Mr. W. H. Barlow, March 6th, 1844; the object of the patentee being to obtain a degree of elasticity together with strength and lightness. Fig. 18 shows one of these hollow metal keys of an irregular but complete tube form. Fig. 19 shows one of them in which an opening is left throughout its length: in this case, however, the patentee considers it desirable that the edges of the iron should butt together. He also proposed some modifications of these hollow iron pins to be used for holding the chairs down upon the sleepers, and also for other engineering purposes. It is reported that two miles of the Midland Railway, in the neighbourhood of Rugby, which was laid with these keys, showed a remarkable difference in the steadiness of the road and the quietness of the joints, as compared with that part of the line laid with wood keys.

Figs. 20 and 21 show a peculiar kind of chair and fastening adopted on the great North of England Railway. In this chair only one solid cheek is used. On the other side the chair has only two parallel flanches, marked *c c* on the figures, and which are sufficiently cut away to allow the rail to be introduced into its place: between these flanches a solid block of cast iron, marked *a*, fitted to correspond with the side of the rail, is secured by a key or wedge *b*, which is driven behind it, and through holes formed in the flanches *c c* for that purpose. In spiking the chairs down upon the sleepers it is usual to interpose a layer of felt between the two.

The following Table presents the principal items included under the title of this Section, as adopted on the several railways named in the first column.

Name of Railway.	Gauge. Ft. In.	Width. Ft. In.	Central space between lines. Ft. In.	Cross or longitudinal sleepers.	Sleepers.		Weight of chairs. lbs.	Distance between supports. Ft. In.	Section of rail similar to fig. in Plate 38.	Weight of rail per lin. yard. lbs.
					Length. Ft. In.	Scantling. Inches.				
Arbroath and Forfar . . .	5 6	28 6	6 5	cross	8 6	8 × 4	14 int. 20 joint.	3 0	Fig. 6.	48
Ardrossan and Johnstone	4 8½	32 0	6 0	cross	8 6		18½	3 0	Fig. 1.	
Birmingham & Gloucester	4 8½	30 0	6 0	cross and long^l^. ties	8 0 ...... 7 2	10 × 5 13 × 6 7 × 3½	10½ int. 24 joint.	2 6	Fig. 2.	56
Brandling Junction . . .	4 8½	24 6	5 2	cross	8 0	8 × 4		3 0	Fig. 6.	
Chester and Birkenhead .	4 9	30 0	6 5	cross	9 0	10 × 5	21 int. 24 joint.		Fig. 7.	56
Chester and Crewe . . .	4 8¾	30 0	6 5	cross	9 0	10 × 4½	20 int. 24 joint.		Fig. 7.	56
Dublin and Kingstown .	4 8½	30 0	7 4½	cross and long^l^. cross ties	6 0 ...... 12 0 apart	7 × 3 12 × 6		3 0	Fig. 1.	45
Durham and Sunderland	4 8½		4 5	cross	7 0	7 dia.	10 int. 14 joint.	3 0	Fig. 7.	42
Eastern Counties	5 0	30 0	6 5	cross	8 6	10 × 4½		3 0	Fig. 1.	75
Edinburgh and Glasgow .	4 8½	28 0		cross	9 0	10 × 4½			Fig. 1.	75
Great Western	7 0	30 0	6 6	long^l^. cross ties	....	12 × 6 6 × 4			Fig. 3.	44 to 62
Lancaster and Preston . .	4 8½	30 0	6 5½	cross	9 0	10 × 5	19½ int. 22½ joint.		Fig. 1.	65
Liverpool and Manchester	4 8½	25 7	5 2	cross	8 6	9 × 4½	26	3 0 to 3 9	Fig. 1.	60 & 75
London and Birmingham	4 8½	30 0	6 5	cross	7 0	9 × 5	26½ int. 31 joint.	3 9 to 4 0	Fig. 1.	65 & 75
London and Brighton . .	4 9	24 0	6 5	cross				3 9	Fig. 1.	76
London and Croydon . .	4 8½	33 10	6 5	long^l^. fixed in cross	...... 9 0	9 × 5 9 × 4½			Fig. 5.	
London & South Western	4 8½	25 0	6 5	cross	9 0	10 × 4½			Fig. 1.	63 & 73
Manchester & Birmingham	4 9	29 0	6 5	cross	9 0	10 × 5			Fig. 7.	65
Manchester and Leeds . .	4 9	30 0	6 5	cross	9 0	11 × 5		3 0	Fig. 7.	56
Midland Counties	4 8½	26 0	6 5	cross	9 0	10 × 5	23½ int. 28 joint.	5 0	Fig. 1.	77
Newcastle and N. Shields	4 8½		5 5	long^l^. on cross	...... 6 0 apart	12 × 6 12 × 6			Fig. 5.	54½
Northern and Eastern . .	5 0	26 5	6 5	cross	9 0	10 × 5		2 1½ & 3 10½	Fig. 1.	
North Midland	4 8¾		6 5	cross	9 0	10 × 5		2 3 & 2 9	Fig. 7. & Fig. 1.	56 65

Many contrivances have been suggested, and several adopted, for enabling locomotive engines and carriages to be transferred from one line of rails to another. With a view to effect this object readily,—so that on occasion the speed shall require to be only slightly diminished, and, at the same time, to do it safely and effectually,—so that the train shall not be in danger either of getting off the rails, or of following the wrong line,—various arrangements of moveable rails or crossings, with apparatus to move them, have been tried. The one most generally adopted, which has in many instances entirely supplanted previous plans, but has not yet been abandoned for any more recent, is shown generally on Plate XL., and in detail on Plate XLI.

Figures 1, 2, and 3, on Plate XL., show three combinations of fixed and moveable rails and apparatus, one or other of which combinations is required, according to the purpose intended. Thus, first, if it is necessary to provide simply means for turning a train out of one line into another, the arrangement shown in fig. 1 is adopted. Or, secondly, if it is required that a train on either line of rails may be turned into the other one, and without backing the train, fig. 2 shows the combination which must be used. Or, thirdly, if it is required that a train shall be enabled to alter its position to any one of three lines of railway, the arrangement exhibited in fig. 3 must be selected.

Each of these arrangements is a combination of a number of two distinct forms of apparatus, known as 'the switch' and 'the points;' the former consisting mainly of a moveable rail or 'tongue,' tapered at the end, and adapted to lie close against the ordinary rail, or to move sufficiently far from it to admit the flanges of the wheels between them; and the latter including tapered terminations for the main rails and the crossing rails at the points where they intersect, and also such guard or check-rails in separate pieces as may be useful in keeping the wheels from swerving out of the intended course, and also from injuring the thin points of the intersections.

In the figures on Plate XL. the switches are uniformly indicated by the letter A, and the crossing points by the letter C. In fig. 3 a peculiar kind of switch is shown, which, from its being adapted to open a communication between three lines, is called a 'three-throw switch:' this is lettered B; and in fig. 2 peculiar crossing points are required, and are lettered D D.

It will be understood, that the only moveable parts of these rails are the 'tongues' of the switches; and to move these, and render them also self-acting, a weighted lever is arranged to act within a cast iron box, called the 'switch box.' The position of this self-acting apparatus is indicated on the figures by the letters S. B.; one of these being required for each single switch, and two for the 'three-throw' switch.

The single crossing, shown at fig. 1, requires two switches, A A, and two crossing points, C C.

The double, or over crossing, shown at fig. 2, requires four switches, AAAA, two common crossing points, C C, and two peculiar crossing points, D D.

The treble crossing, shown at fig. 3, requires one three-throw switch, B, two common switches, A A, and five crossing points, C C C C C.

The details of these parts are given on Plate XLI., whereon, fig. 1, A is an enlarged plan of a single switch. Fig. 2, B is an enlarged plan of a three-throw switch. Fig. 3, C shows the parts of a common crossing. Fig. 4, D is an enlarged plan of the peculiar crossing points, of which two are required for the double crossing, shown in fig. 2, Plate XL. The two figs. 5 and 6, marked S. B., give two sectional views of the switch box, with the lever apparatus for moving the tongues of the switches. The figs. 7 to 12 are sectional views of the several kinds of chairs required for a single switch; the letters *a*, *b*, *c*, *d*, *e*, and *f*, on these figures, show the chairs required at the several points, similarly marked on the plan A, fig. 1. These details are adapted for double **T** rails. The chair *a*, fig. 7, is similar to the ordinary chairs, but made with two similar cheeks, and sufficiently wide to hold the two rails, with a large wooden key between them. The chairs required at a^1, a^2, a^3, are exactly similar to this, but of various lengths. The chair *b* is the same as *a*, but much wider, in order to accommodate the three rails which occur at that point, as shown on the plan. At the point *c* a peculiar chair is required, shown at fig. 9. The main rail, marked *m* on the plan, is here stopped, and thinned off, to enable the flanch of the wheel to take either line, according to the position of the switch tongue, without encountering the square end of the rail. The chair *c* is therefore provided with a strong shoulder, against which the point of the main rail and the check or guard-rail are bolted. The switch tongue or moveable rail extends from the point *f* (at which it turns) to the point *d*, where it opens sufficiently wide to admit the flanch of the wheel to run in between it and the main rail, m^1, fig. 1. At the point *f* a chair is used, shown at fig. 12, to which the switch tongue, *s t*, is bolted. The upper part of the chair turns upon the lower part, and is connected by a strong bolt, with countersunk head. At the several points marked *d*, d^1, d^2, d^3, and d^4, a chair, similar to that shown at fig. 10, is required. The main rail, m^1, is bolted to one cheek of each of these chairs, and the switch tongue marked *s t*, in fig. 10, slides over a plain seating formed on the chairs, according to the motion required, and is prevented from opening too wide by a strong cheek formed on each of the chairs. Fig. 11 is a section of a peculiar chair required at *e* on the plan, fig. 1, in which the main rail, m^1, and the end of the fixed rail, *r*, are secured by wooden keys. The position of the switch tongue, shown in full lines, is that which it has when open, the main line being open, and the crossing not in use. When the switch tongue is brought close against the main rail, m^1, the wheels of a train coming in the direction shown by the single arrow will be received at the point *d* upon the tongue, and thus taken off the main line. The main line, when open in one direction, is also evidently open in the other, without any movement of the tongue. The wheels of a train coming out from the crossing on the rails, *r r*, in the direction shown by the two arrows, are allowed by the construction of the lever apparatus to press the tongue against the main rail, m^1, thus closing the switch without any attention on the part of the switch-man: as soon as the wheels pass off the point *d* of the tongue, it immediately opens by the self-action of the lever apparatus, thus leaving the main line again free for traffic in both directions.

The tongue is moved with a wrought iron rod, marked *z*, which is fixed to the tongue, but passes freely through a hole in the main rail, m^1. The other end of the rod, *z*, is connected by a pin, with a crank marked *c*, in figs. 5 and 6, the shaft, *s*, of which turns in fixed bearings, *b b*, on the sides of the switch box. This crank is also formed to be connected with a rod, *r*, upon which circular weights, *w*, are held; it has also a socket, into which a handle, *h*, fits. This handle is sufficiently long to be conveniently used by the switch-man. When the main line is open, the handle *h* is in the position shown by full lines, being retained by the weights *w*. In order to close the switch, the handle must be forced back into the dotted position, thus throwing the crank round and raising the weights. This is done by the flanches of the wheels when coming out of the crossing; the only operation, therefore, which requires to be performed by the switch-man is the closing of the tongue, in order to throw a train into the crossing. The switch box is supported in a timber frame, sunk level with the ground. The check or guard-rail prevents the wheels pressing too severely against the tongue.

In the crossing, fig. 3, *m r* shows the main rail, and *c r* the crossing rails; at the point *p* the two rails are closely fitted together, the top flanches being notched to correspond, and the webs thinned off: they are accurately planed on the meeting surfaces, and bolted together. Each of the other rails which would meet at this intersection is turned off at *t t*. The check or guard-rail is to prevent the wheels of carriages on the crossing from knocking against and injuring the tapered point *p*.

The action of the three-throw switch will be understood from the description just given of the single switch; the three-throw requires two levers and apparatus, one of the rods of which, z^1, passes freely through one of the main rails and one of the switch tongues. The main rails are marked *m m*. The rails and tongues which are used by a train entering the crossing in the direction of the arrow are marked *l* and *r*, according as it is required to cross to the left or to the right hand respectively. For this entire apparatus four switch tongues are required, two long, and two short, marked *s t*; two connecting rods, marked *r*, are also needed for coupling the tongues, so that they may be moved together. All the tongues turn on the line *c c*.

From the description already given of the single crossing C, fig. 3, the double one D, fig. 4, will be readily understood. Chairs of peculiar forms are of course required for each of these arrangements, and are always supplied together with the bolts, nuts, pins, and keys complete.

In order to change the position of engines and carriages within a more limited space than that required for a crossing, several forms of *turn-plate* or *turn-table* have been adopted. These are usually made circular on plan, so as to turn within a fixed ring, and of sufficient size to contain one carriage only. Turn-tables are sometimes made large enough to turn an engine and tender together: these require a circular rack and pinion.

One of the best constructions of turn-table adapted to a six-wheeled carriage is shown on Plate XLII., in which fig. 1 is a quarter-plan of the top of the table; fig. 2, a quarter-plan of the moving apparatus and fixed framing, which constitute the base and the casing of the table. Fig. 3 is a cross section of the entire apparatus; fig. 4, an elevation of part of the casing; and fig. 5, a side view of one of the latches by which the moving table is secured in each of its positions: *a a* are solid rails of wrought iron fixed on the lid to correspond with the gauge of the line, and forming two sets of rails or tracks crossing the lid at right angles to each other. The covering plates, *b b*, which form the lid of the table, are of cast iron, corrugated on the upper surface, and resting in fillets formed on the cast iron top framing, *c* and *m*. The lower framing is also of cast iron, formed with arms, *i i*, with a bearing rim, *q q*, and a hollow central boss, *s s*. The upper framing is also perforated in the centre at *u u*. The moving top framing is supported by resting near the periphery upon eight cast iron conical rollers, which turn upon the bearing rim, *q*, of the lower framing. It is supported at the centre also by bolts passing through the rim, *v*, of a strong wrought centre pin, marked *d*. This pin turns in a gun-metal step, *r*, supported in a socket, *t t*, which is held in the lower framing, *s s*; the interior of this socket, and of the central hole in the top framing, are truly bored to fit the turned surface of the pin *d*. The rollers, *e e*, are held in their places by rods, *f f*, which rods are screwed in a wrought ring, *w w*, and passed through a light framing formed of a ring, *h h*, of flat iron, and of a continuous bar, *g g*, of angle iron. The bar and the ring being bolted together, the ring *w w* fits a shoulder formed on the socket *t t*. The bearing rims *c* and *q* of the upper and lower framings are accurately planed to fit the turned surface of the conical rollers *e e*.

The casing consists of eight segmental pieces, *j j*, bolted together through meeting flanches, *p p*, and bolted also to ears, *o o*, cast on the lower framing. The latch, *k*, is fastened by a pin to a small bracket bolted to the casing. Four of these latches are thus fixed, and are dropped into notches, *l*, fig. 5, to retain the table in each of its positions. A man-hole and lid are provided at *x*, to give access to the interior, for oiling the rollers, &c.

It is evidently essential, that for these turn-tables an unyielding foundation should be secured. For want of this, many tables formed with cast iron framings have failed, and been speedily broken. In high embankments, the requisite solidity can seldom be obtained without constructing a well of brickwork, on the rim of which, and on a central pier, the table is fixed. To obviate this difficulty, tables have been designed, and found to answer well, with centre pins of a much extended length. The periphery of tables thus constructed is supported by strut-bars, which are fixed into a jacket revolving upon the lower part of the long centre pin.

In the description of the crossings, it should have been mentioned, that merely for the purpose of removing carriages or trains out of the main line, a side line of extra rails is commonly provided. This side line will run parallel with the main line, or divergent from it, if the site is more convenient for that direction. Such siding is made to communicate with the main line by a single switch apparatus and one crossing point, in which the other end of the siding rails leads into a carriage or engine-shed, and is there stopped; or the siding rails communicate at both ends with the main line, by two single switches and crossing points. This latter arrangement is the one usually adopted in arranging sidings into which slow or luggage trains are run temporarily, in order to leave the main line clear for a faster train, which is expected to overtake or to pass the slow train. With this arrangement, the train is enabled to leave the siding, and resume its position upon the main line, without backing out; but a very serious objection exists to this siding communicating at both ends with the main line, for the gaping end of the switch is thus exposed to the trains passing along the main line in one direction; and therefore, to insure safety, every train that passes requires to be stopped, or, at the least, its speed very materially slackened, lest by any accidental cause the switch tongue should be closed, and thus throw the train into the siding, or partly closed, and there clogged, in which case the wheel would meet the end of the tongue, and thus inevitably force the carriage or carriages off the rails altogether. Sidings which communicate with the main line by one switch only, may, on the other hand, be so arranged that trains passing customarily on that main line shall never '*meet* the points,' that is, the end of the switch tongue. In this case the switch is perfectly safe, and requires manual attention only when carriages are to be driven into the siding.

In order to turn an engine and tender together from one line of rails to another, without using the large turn-table which would be required for this purpose, the simple apparatus in use at the Greenwich station may be applied. This consists of two cast iron girders, about 26 feet in length, (according to the total length of engine and tender,) fixed parallel to each other by cross braces, and adapted on the top surface for the wheels in the manner of rails. These girders are supported on four pairs of small rollers, two pairs near the ends, and two pairs near the centre; and these rollers work upon circular rims of metal fixed in the ground or foundation. A winch and pinion are provided at one end of these girders, which, with their framing, are made to revolve within a circular rim, having an internal cog-wheel or rack, into which the pinion is worked by the winch.

If it be desired to reverse the direction of a train, and to avoid the expense of a turn-table, or to serve its purpose temporarily, and there is sufficient space, two short siding lines may be laid in from the main line, diverging from it, but converging towards each, and meeting at a short distance in the manner of the two sides of the letter V, with a piece of straight line continuing from their point of meeting, so that the whole resembles the letter Y. A carriage or train may be turned down one of these sidings, run along the piece of straight line to clear the switch, and then backed, along the other siding, into the main line, which it enters in the opposite direction to that in which it left it. In order to shift a carriage from one line of rails to another, within a short distance, such as under a station-roof, where no space can be had for a crossing, a traversing platform is sometimes adopted, of sufficient length to hold one carriage, wide enough to have two sets of rails fastened upon it, and being fitted upon traversing rollers, and adapted to move to the one side or the other as desired. This apparatus, however, may be regarded as forming a part of the station fittings, and will therefore be described and illustrated in the Section of this Paper devoted to the description of those works.

The completion of the railway ready for the buildings and locomotive stock, which will form the subject of the concluding Sections of this Paper, to be given in a subsequent volume, includes some other matters of a secondary character, but of which the past experience may be usefully quoted with brevity. These are, the fencing and drainage of the permanent way, and approach roads crossing the railway over or under bridges; and the construction of level crossings and gates, where the railway and intersecting roads cross each other on a level.

A good permanent fencing for the sides of the line consists of oak posts 4 inches by 6 inches, 8 feet long, and standing 3 feet 6 inches or 4 feet out of the ground, and 9 feet apart from centre to centre. They may be squared above ground, but are better left rough below, if it saves labour and does not waste material. Midway between each two contiguous posts are smaller ones, 3 inches by 6 inches, and only 5 feet long, the lower ends being cut taper, and driven 1 foot 6 inches into the ground; or the intermediate post may be only 3×2 inches, and spiked to the inner side of the rails. The former makes much the best fence, but the mortising is of course expensive in labour. The rails, of which there are four, are also of oak, and are 5 inches deep by 2½ inches wide, mortised and joined in the principal posts, and passing through the minor ones. Or the rails are placed diagonally, in which case they may be 3½ inches square. The principal posts should be bound with iron hooping. Sometimes five or more rails will be required, and the railing to stand 4 feet above the ground: three wooden rails, with two intermediate wires, form a good fence, and one which has been much adopted. A very secure, but comparatively expensive fence, is formed with three rails above, and paled for the lower half of its height. On some of the railways an entire wire fence is employed. This, however, requires a particular class of workmen to fix and to repair it, and a breaking of one of the wires extends the mischief and the insecurity for a great length, instead of being confined to one spot, as in wooden fences. Quicks should be planted within the fencing.

In the neighbourhood of stations, &c., where a very secure fence is required, an open batten fence is commonly set up. This consists of squared posts standing 9 feet apart, and 9 feet long, being 3 feet in the ground, and standing 6 feet above it, and are 4 inches by 6 inches. Into these posts three rails are mortised: these rails are halves of square timber, 4 × 4 inches, sawn diagonally and connected into the posts, so that the diagonal of the square is vertical, and stands $1\frac{1}{2}$ inch within the outer side of the post. Upon the outer side of these rails the battens, 3 inches by $1\frac{1}{2}$ inch, are secured 3″ apart in the clear, ranging in height level with the top of the posts, and within 2 inches of the ground. The posts and the battens will thus range flush on the outer side of the fence, and the tops of them should be bevelled off from the centre. To form a close fence, feather-edged boards are used instead of battens; these should be 1 inch thick at one edge, and $\frac{3}{8}$ths of an inch at the other, and made to lap over 2 or $2\frac{1}{2}$ inches.

In districts where stone is abundant, the sides of the line are frequently protected by stone walls built dry, with coping set in mortar, from 4 to 5 feet high, 12″ to 18″ thick at top, 21″ to 27″ at bottom, and battering on both sides.

The drainage of the earth-works of railways has already been described in the first Section, in which also a general account was given of the side ditches. We have now only to notice some of the methods adopted for completing the drainage of the upper surface of the railway. Across the ballasting, gullets are commonly cut, leading the surface water into the side ditches or drains. Besides the side drains, central longitudinal drains are sometimes formed, in cuttings and embankments, of rubble-work or of perforated tiles, and which communicate, by cross drains, from 10 to 25 yards apart, of similar formation, with the open side drains. Where the cuttings are through sand or other unsteady materials, the side drains formed at the base of the cutting are frequently protected by a covering of flags or rough stones. In districts where stone abounds, these drains are sometimes built of stone, the bottom being formed of flags. In deep cuttings, where capacious drains are required, it is sometimes found desirable to build the side drains of brick-work, either left open at top, or covered with flag stone, with openings or cesspools at convenient distances, to take off the surface water. A very durable drain is thus secured, and the cost of construction of drains, whether of stone or brick, is partly compensated by the less width of land required, as their sides may of course be formed much steeper than those of an open trench or ditch. The side drains are also, occasionally, formed of circular perforated tiles or tubes of large diameter, or of brick-work of a circular or other culvert form. Semicircular half-brick open drains are used occasionally for the sides of cuttings. Under-ground drains are frequently formed of semicircular perforated tiles, based on rough stones, flagging, or paving tiles.

Throughout the entire length of the railway, four parallel water-courses should be formed, that is, two on each side. The tops of the slopes of the cuttings are protected by a fence and mound, and outside these a field drain is required for the adjacent land. At the feet of the slopes also drains are wanted to receive the water from the banks, and also from the surface of the railway. The bases of the embankments require drains to receive the water from the railway and from the surface of the banks; and also other parallel drains outside the fences, to protect them and the mounds from the drainage of the adjacent land. The surfaces of the slopes, both of cuttings and of embankments, must be drained by open channels, as already described, conducting the surface water into the lower drains. The sizes of the drains must of course be determined by the extent of surface to be drained, and by the quantity of water to be provided for: the slope at which the sides of open trenches may be formed must depend upon the nature of the soil through which they are cut. They will usually stand well at 1 to 1, if through clay or other tenacious stratum. Several, however, are formed at 1½ to 1, and even as flat as 2½ to 1.

The width of land required for a railway will be determined by the following conditions, which will occur in the order there stated. First, the gauge;—Second, number of lines of railway;—Third, intermediate spaces and side spaces;—Fourth, depth of cutting, or height of embankment;—Fifth, inclination of slopes;—and Sixth, width required beyond the base of embankment or top edge of cutting for ditch, fence, and mound.

In the making or altering of common roads approaching bridges built over or under a railway, the maximum rate of inclination is, in this country, at present defined by the Parliamentary Standing Orders, as follows:

"Where the level of any road shall be altered in making any railway, the ascent of any turnpike road shall not be more than 1 foot in 30 feet, and of any other public carriage road not more than 1 foot in 20 feet, unless a Report from some Officer of the Railway Department of the Board of Trade shall be laid before the Committee on the Bill, recommending that steeper ascents than the above may be allowed, with the reasons and facts upon which such opinion is founded, and the Committee shall report in favour of such recommendation." It is also specified in the same Order "that a good and sufficient fence, of 4 feet high at the least, shall be made on each side of every bridge which shall be erected." A fence which has been deemed "good and sufficient," and been much used, consists of posts 7 feet long, 4 in. × 5 in., standing 4 feet above the ground, and placed 8 feet apart,—with three rails, 3 inches by $1\frac{1}{2}$ inch, mortised into the posts, besides a top rail, $3\frac{1}{2}$ inches square, placed diagonally, and resting in angular notches cut on the tops of the posts. An iron strap, $1\frac{1}{2}$ inch by $\frac{5}{8}$ of an inch thick, passes over the rail and embraces the post for a length downwards of about 18 or 20 inches on each side, and is secured by clout nails or screws. The approach road will require a good metalling on the surface, and well rounded; and the slopes must be efficiently drained in a similar manner to the sides of the railway.

Where crossings of the railway and other roads on the same level are permitted, that part of the railway destined for public traffic must be well paved and drained, and the rails require protection from the wear of such traffic, without in any manner interrupting the space required for the flanges of the wheels of the railway carriages and engines. For this purpose guard-rails are used, as shown on Plate XLI., vol. vii. According as the intersecting road is a turnpike or public road, or one only required for communicating between fields or farms, a double or a single width of level crossing is provided. For a single carriage-way, not only are the rails fixed between high flanges, but the channel for the traffic across them is also defined by metal guard-plates, sufficiently wide to allow for various widths between the wheels, and having a vertical flange on one side, similar to the construction of the cart-way on swing bridges over docks and basins. Those parts of the side drains of the railway which cross the level crossings are covered up, and receive the discharge from other drains formed along the sides of the road which crosses the railway. The intermediate spaces between the rails, and for the full width of the road which crosses them, are filled up with pitch-paving, laid regularly, and well grouted in. Across all these intersections suitable gates are indispensable; they should be made each in two halves, for the double crossing, and usually shut across the common road, being opened to the road and shut across the railway only for such brief intervals as the traffic may require, and at such times as it is known that no trains in the ordinary course can reach the gates. For each double crossing two pairs of these gates are required, and the gate-posts must occupy the four angles of a square, so that each pair of gates shall close together, either in the centre of the road or the railway. Each gate should have a semicircular disc of wood at the swinging end, painted white, so that when closed, a large circle, say of 4 feet diameter, is presented on approaching the gates. For conspicuity by night, and in fogs, coloured lamps should be fixed at the same ends of the gates. The construction of these crossings, and the forms of rails used, are shown in detail on the figures of Plate XLI., published in the seventh volume, and already referred to.

The average quantities, *per mile*, of the several items which are involved in the formation of a double line of railway, of the 4 ft. $8\frac{1}{2}$-in. gauge, up to the completion of the permanent way, and exclusive of the stations and buildings, and locomotive and carrying stock, may be computed as follows:

The quantity of excavations in 342 miles of double line of railway (comprised in ten railways) amounted to 35,338,000 cubic yards, giving an average of about 103,330 yards per mile, or 58·71 cubic yards of earth-work for each yard forward of the line. Assuming the width of the formation level to be 10 yards, or 30 feet (which is about the average), with an additional width of 5 yards on each side, for ditches, hedges, &c., the slopes at $1\frac{1}{2}$ base to 1 of height,—and also assuming the whole line to be either in cutting or embankment, of an average depth or height of 11 feet,—we shall require 56·73 cubic yards of earth-work per yard forward of the line. This is sufficiently near to the actual average of 58·71 yards to answer the purpose of this general calculation. The average width of land required will thus be

$$\overset{\text{Central width.}}{30} + \overbrace{16{\cdot}5 + 16{\cdot}5}^{\text{Base of slopes.}} + \overbrace{15 + 15}^{\text{Ditches, \&c.}} = 93 \text{ feet, or } 31 \text{ yards,}$$

which will give about $11\frac{1}{4}$ acres of land per mile. Allowing for severance, &c., this may be assumed at 12 acres.

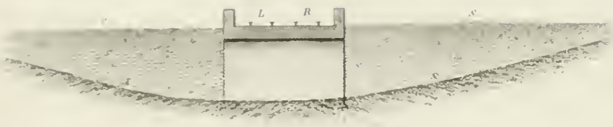
The quantity of ballasting, 30 feet wide, and 18 inches thick, will equal 5 cubic yards per yard forward, or 8800 cubic yards per mile.

The sleepers, transverse, 8 feet long, and 10 inches by 5 inches, placed 2 feet 6 inches apart, will require 11,733 cubic feet, or 235 loads of timber; or 4224 sleepers per mile.

RAILWAY BRIDGES.

A

Fig. 1



B

Fig. 1

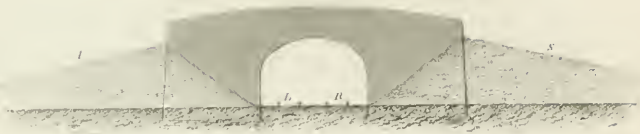
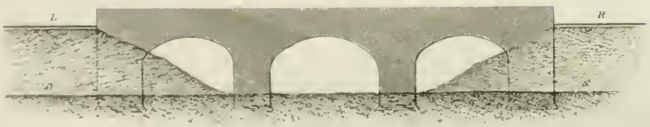


Fig. 2



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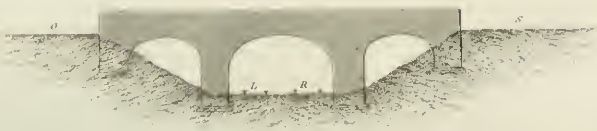
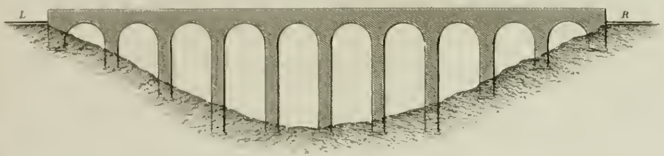


Fig. 3.



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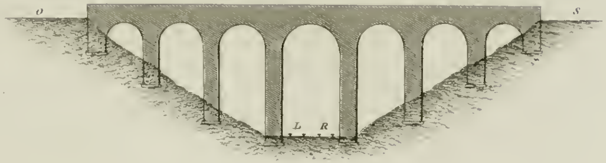


Fig. 4

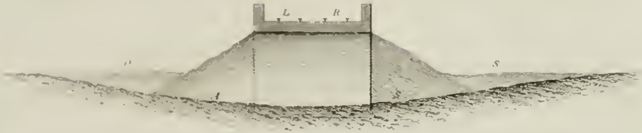
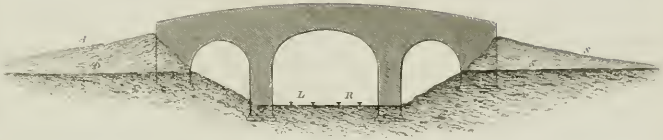


Fig. 4



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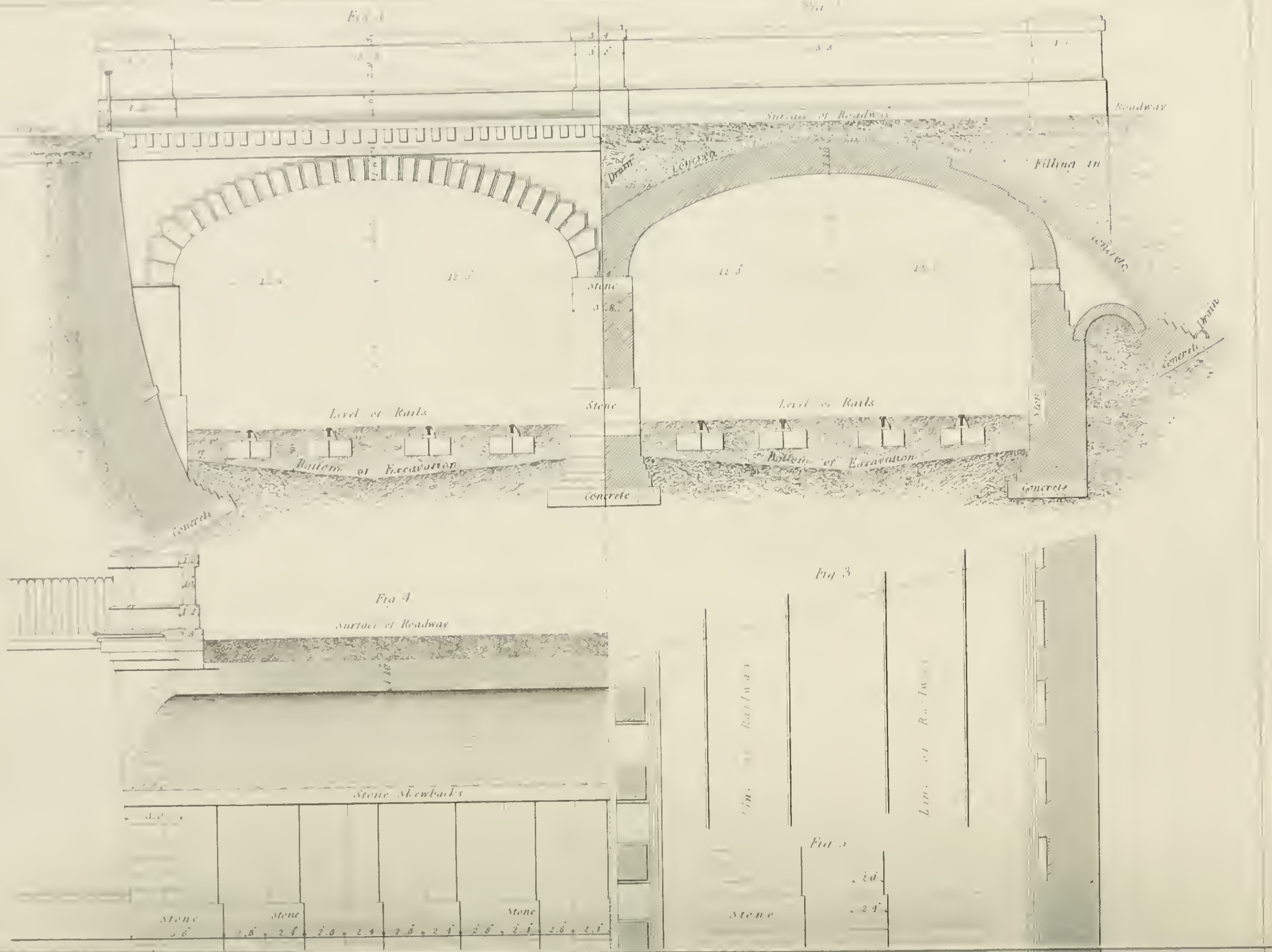


Fig. 1
Fig. 2
Roadway
Surface of Roadway
Filling in
Drain
Concrete
Stone
3.8
12.5
Level of Rails
Bottom of Excavation
Concrete
Drain
Fig. 3
Line of Railway
Line of Railway
Fig. 4
Surface of Roadway
Stone Skewbacks
Stone
2.8
2.4
Fig. 5
2.0
2.4
Stone

Fig 6

Fig 7

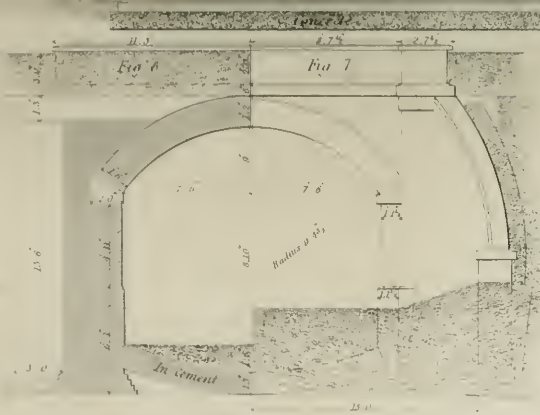


Fig 10

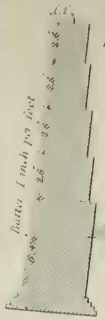


Fig 8

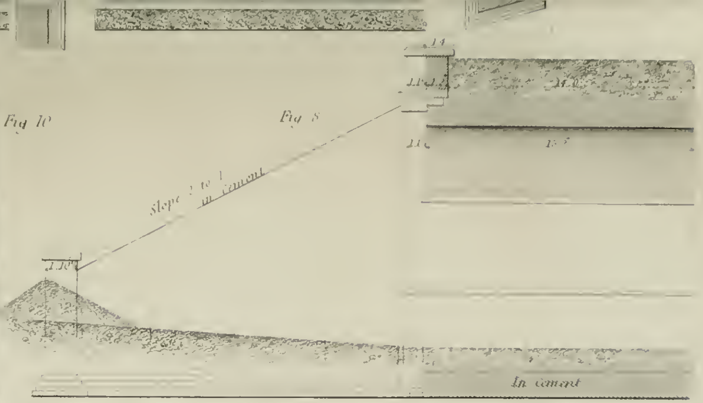
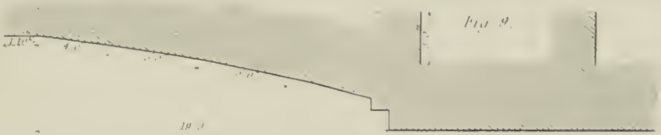


Fig 9.



Scale

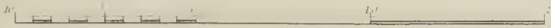


Fig 11

Fig 12

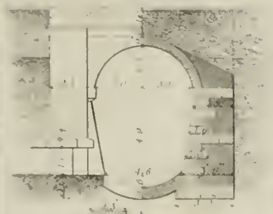


Fig 15

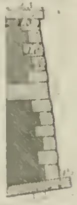


Fig 13

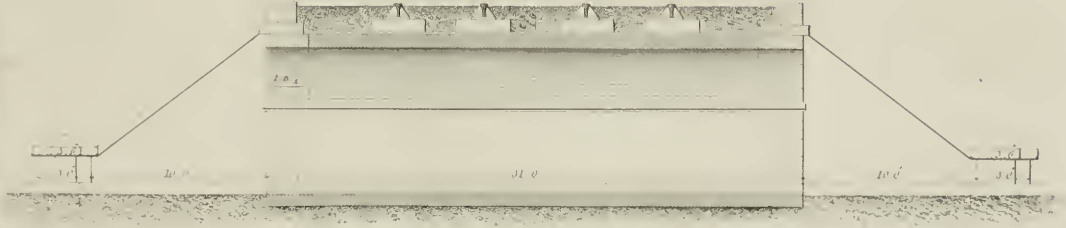
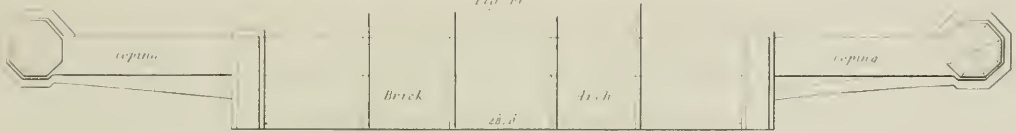


Fig 14



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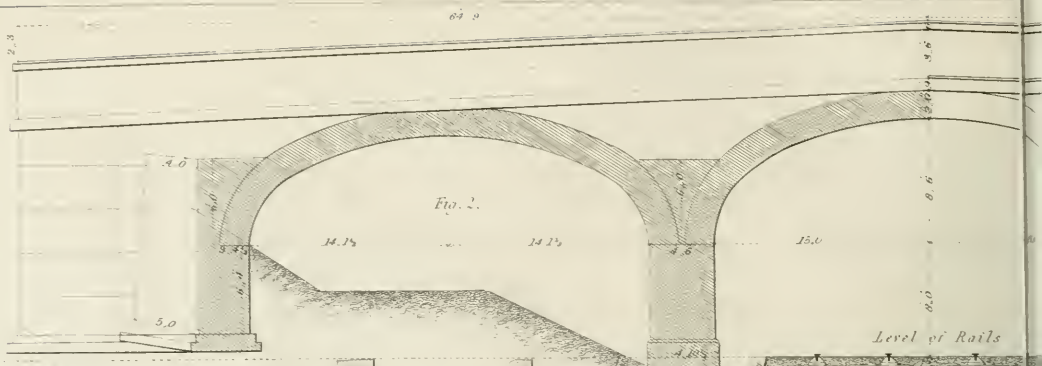
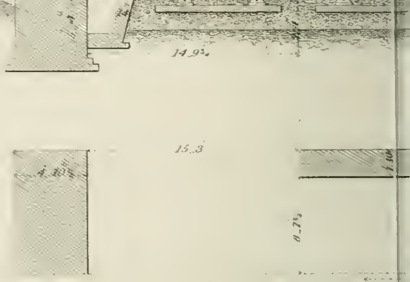


Fig. 2.



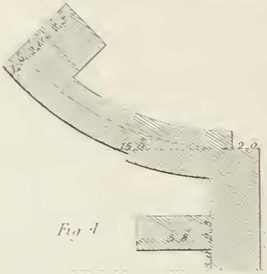


Fig 4

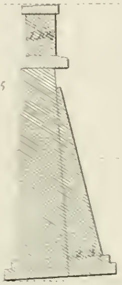


Fig 5

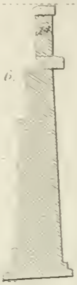


Fig 6.

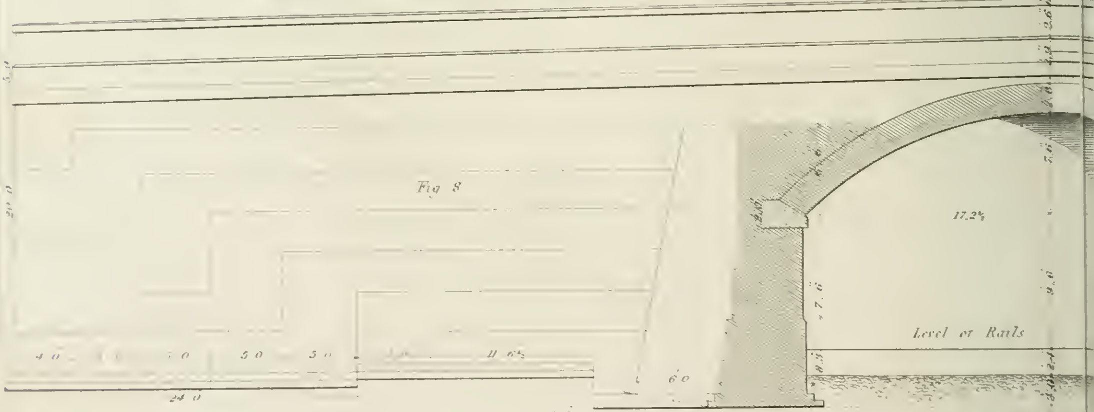


Fig 8

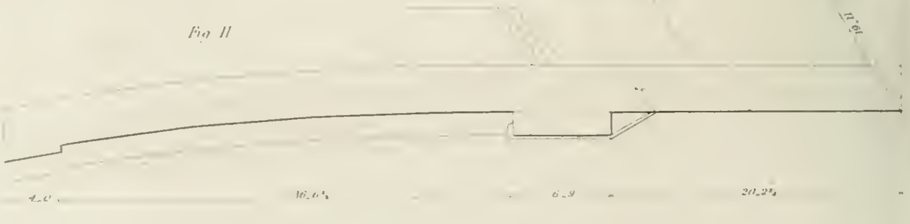


Fig 11

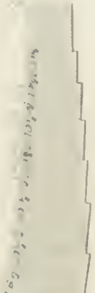
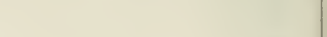


Fig 14



Scale

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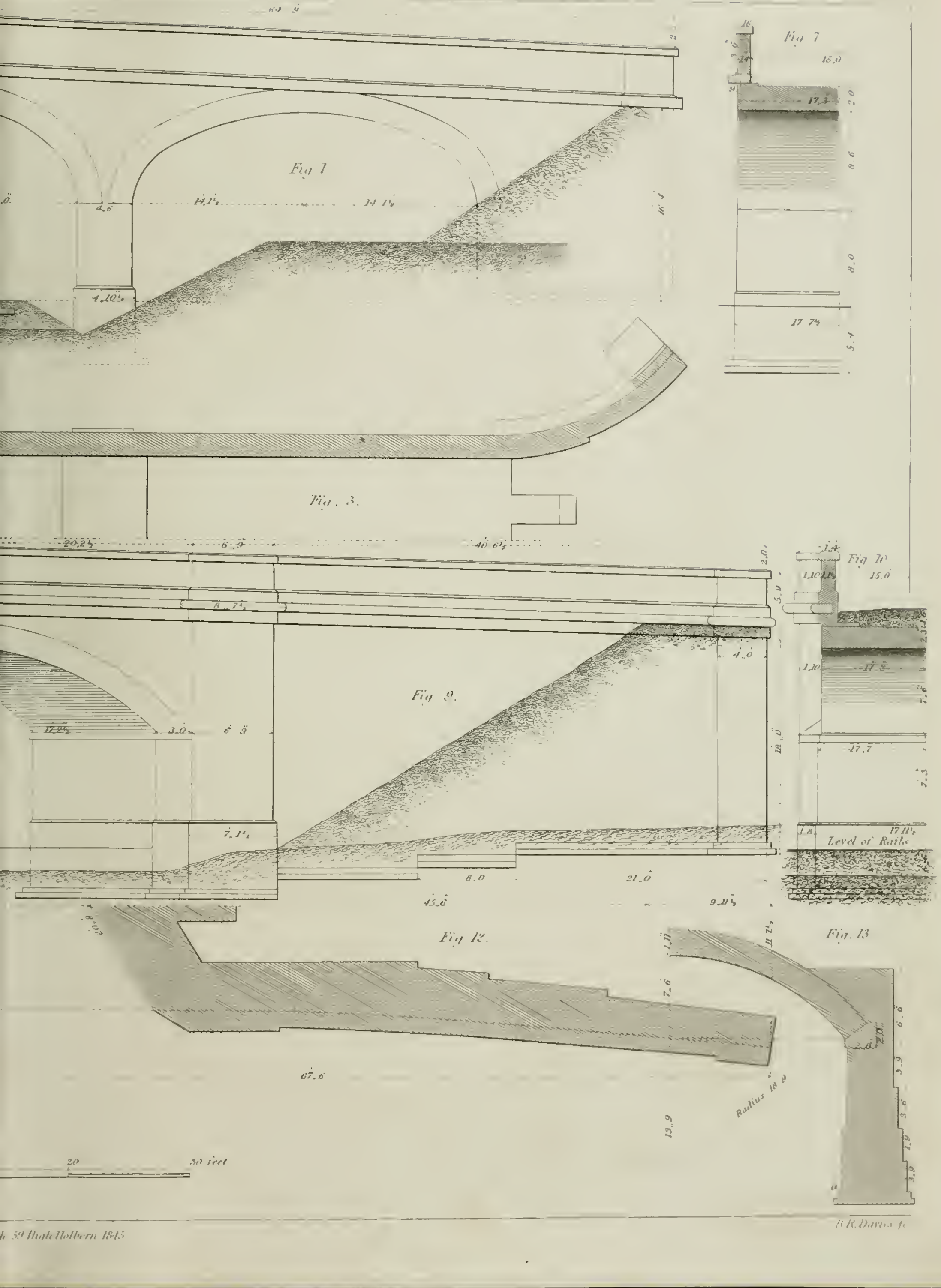

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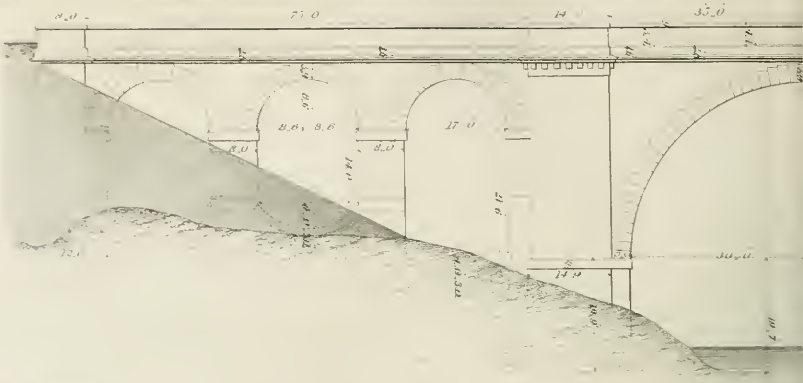
Fig. 1



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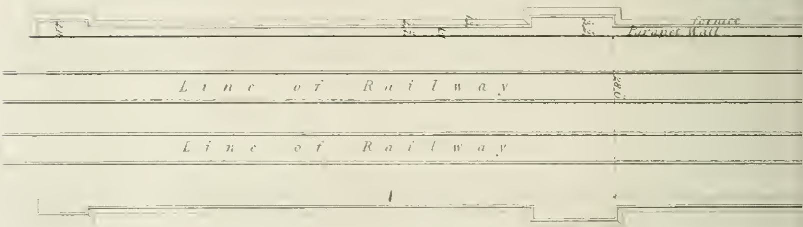

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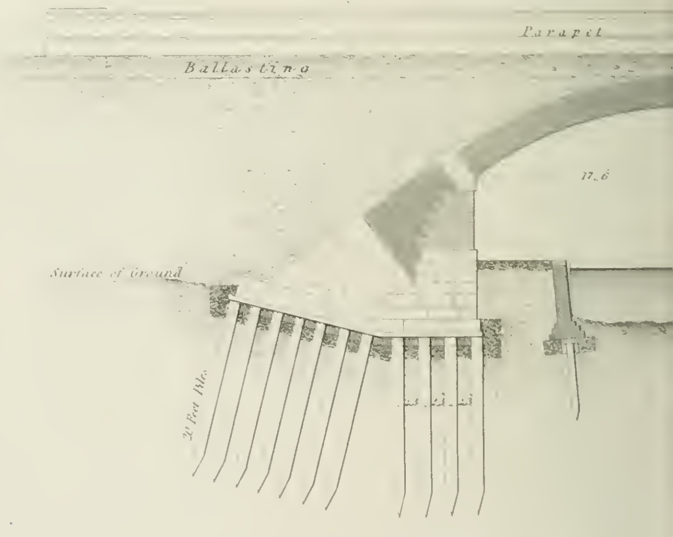

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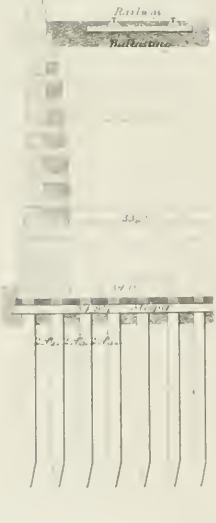

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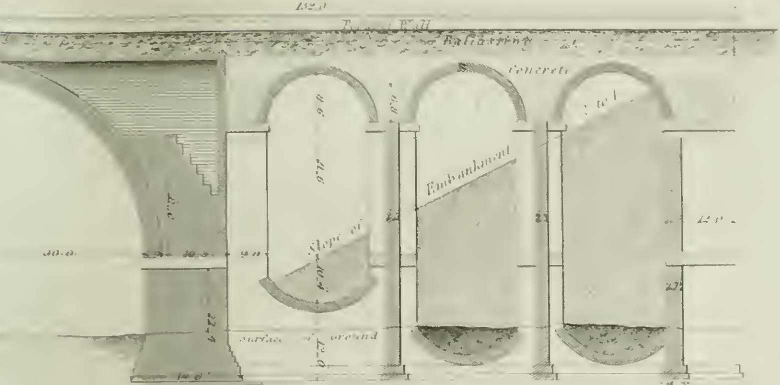

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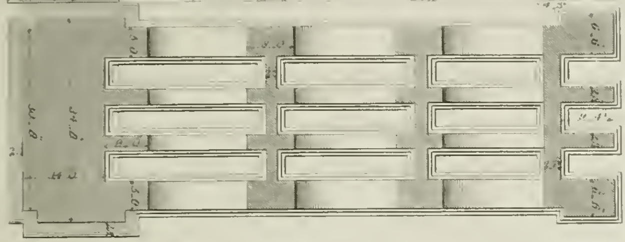

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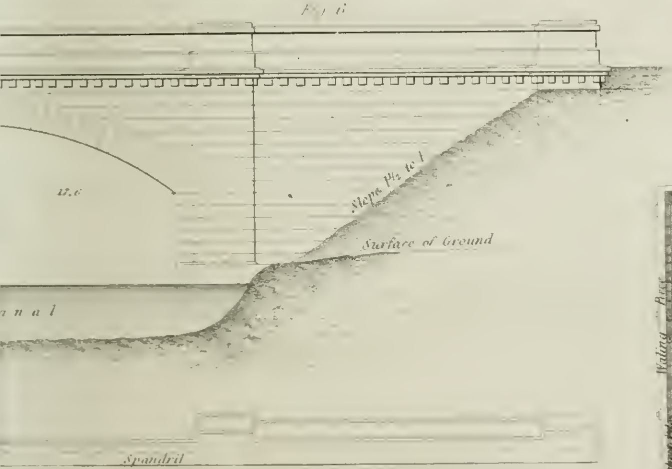

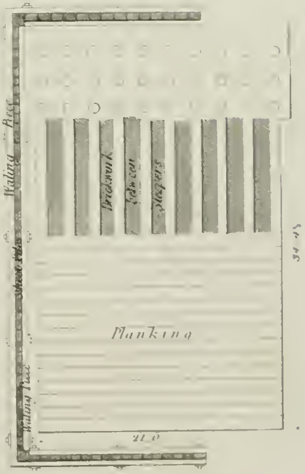

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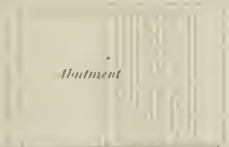

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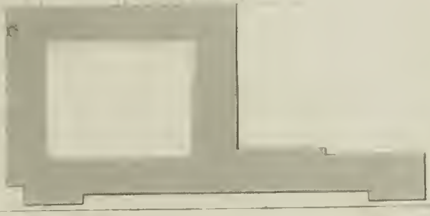

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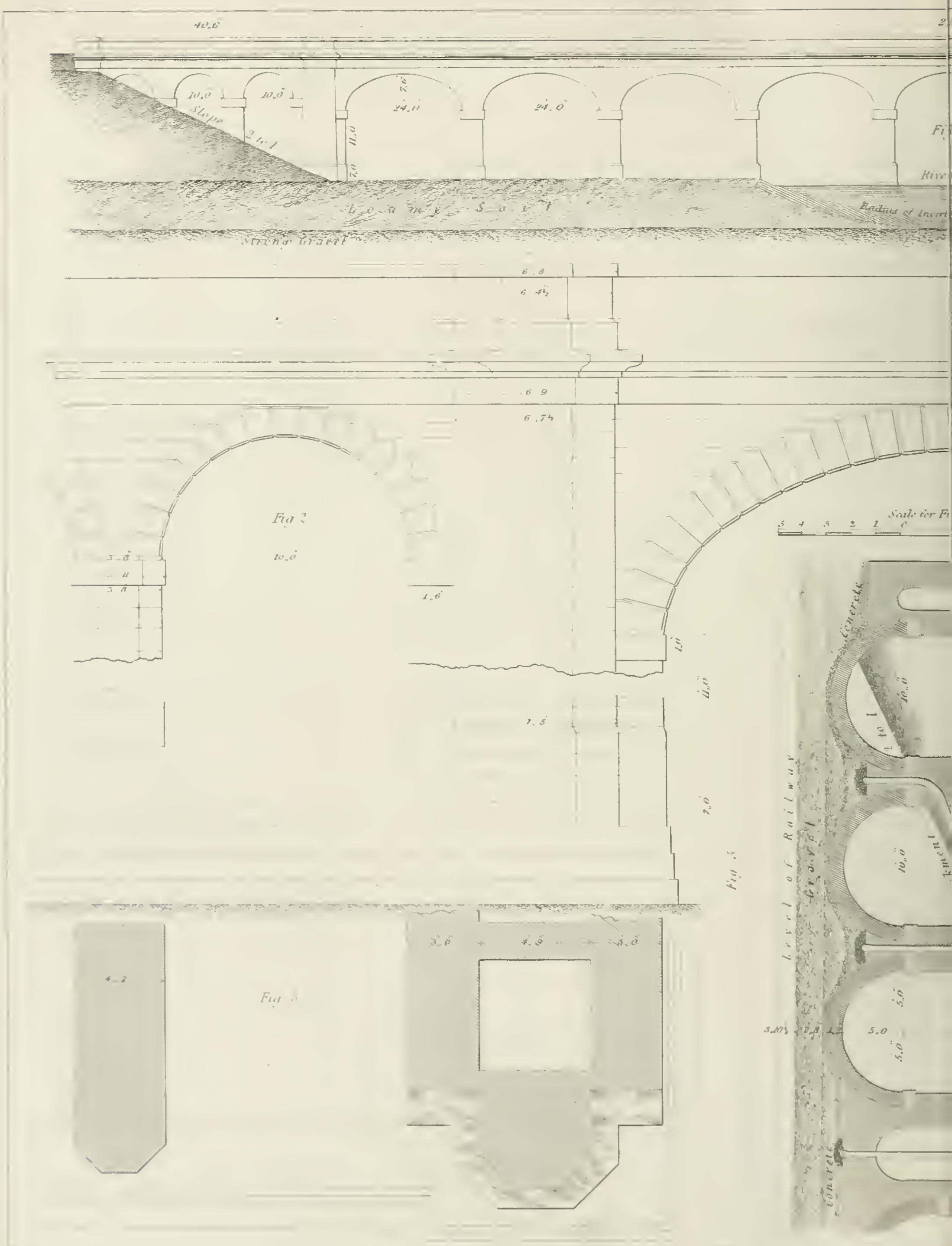

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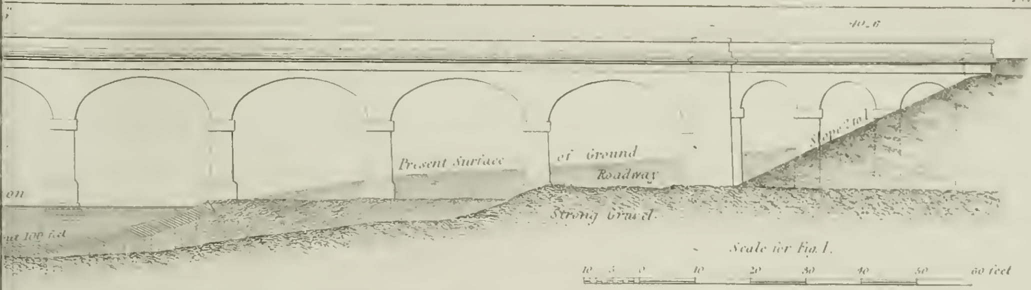

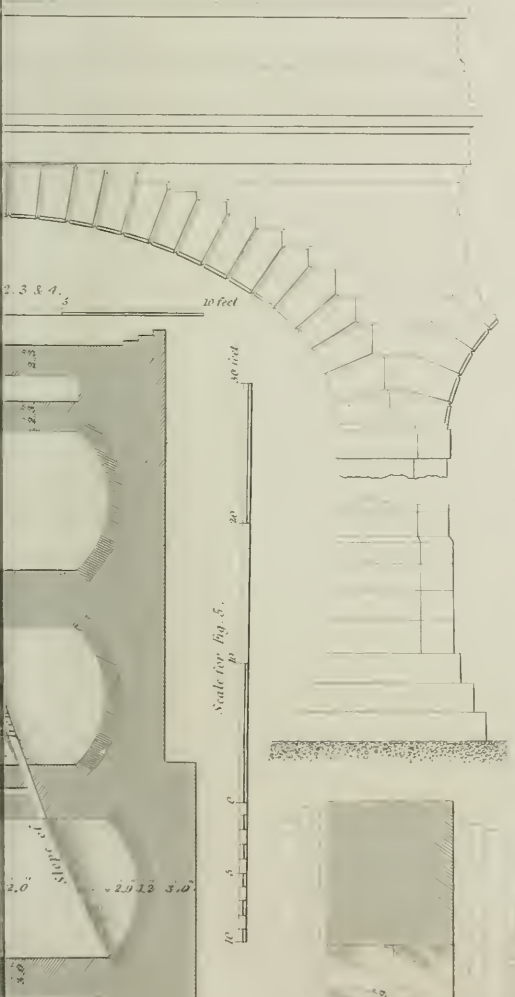

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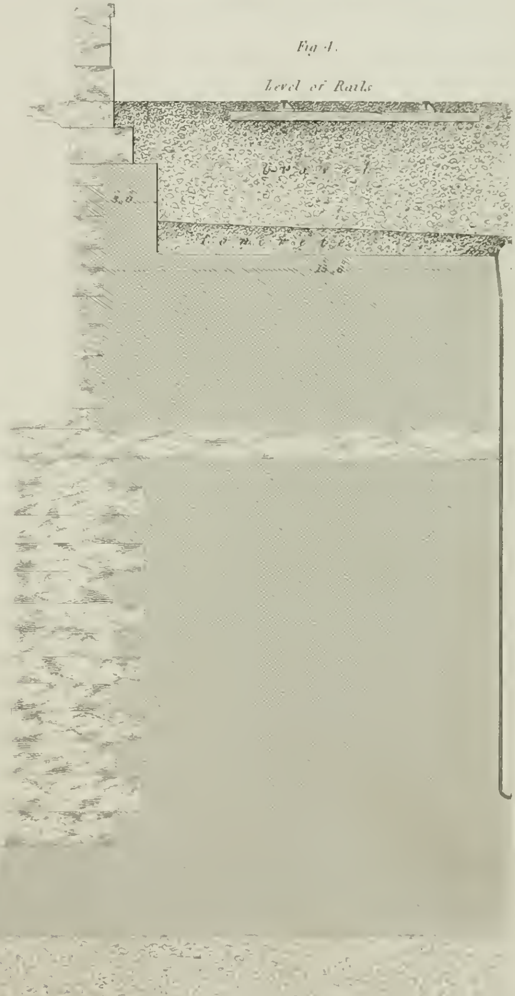

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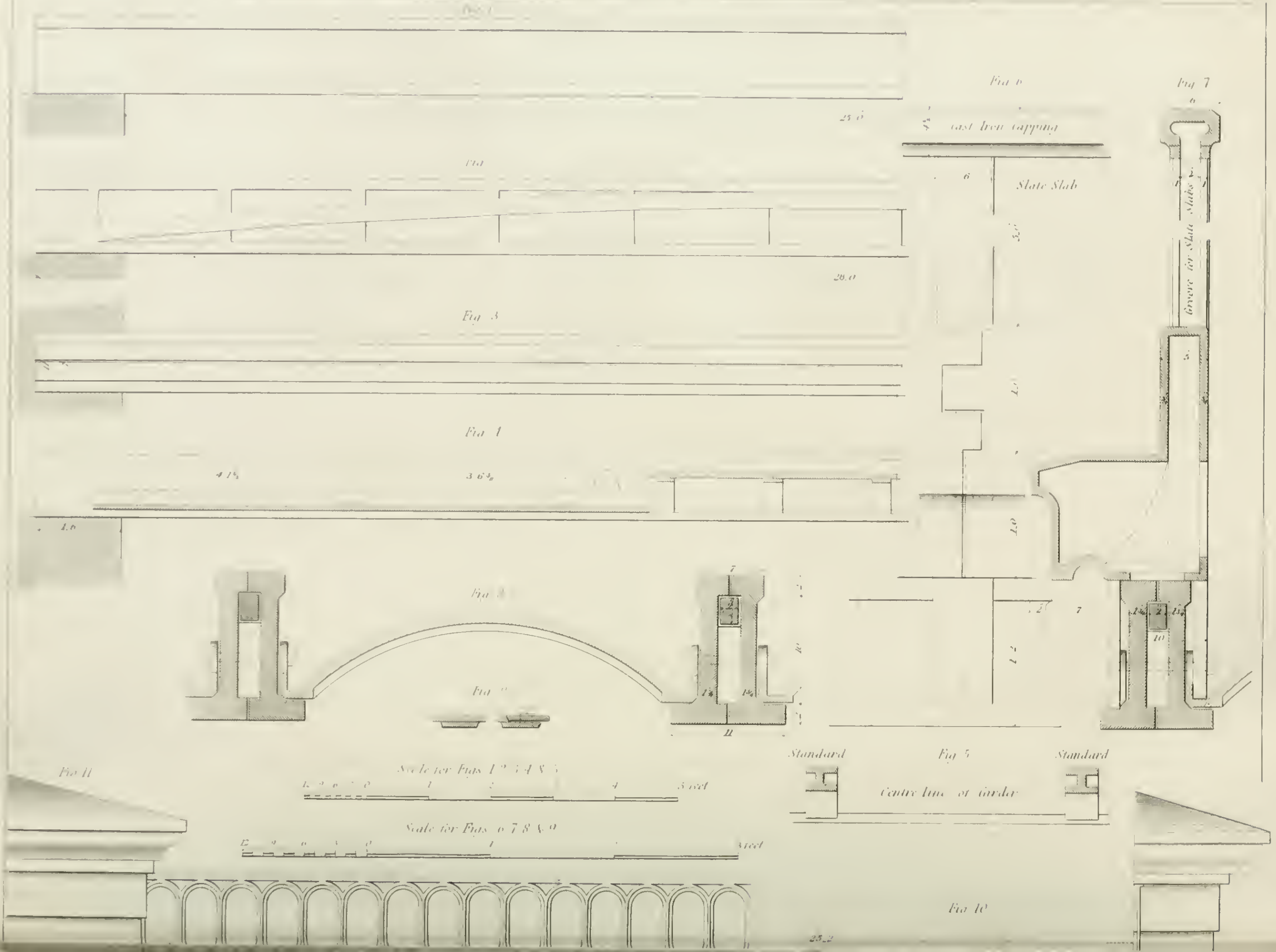

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Scale for Figs 6 7 8 & 9

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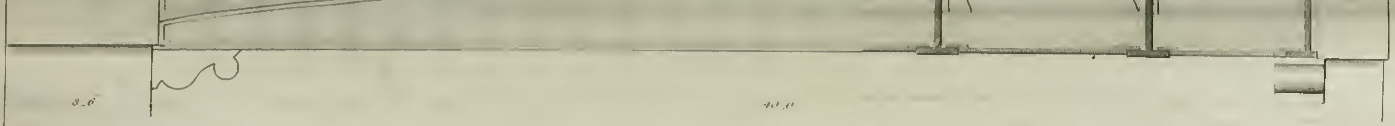

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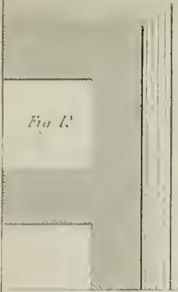


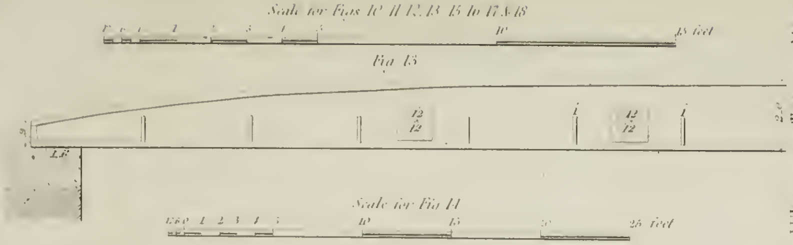
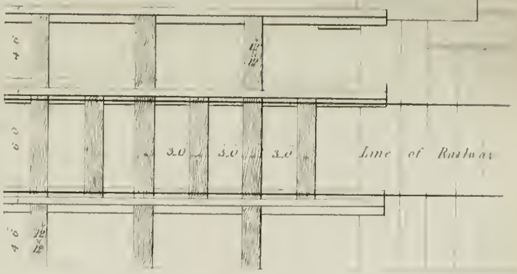


Fig 15

Fig 11



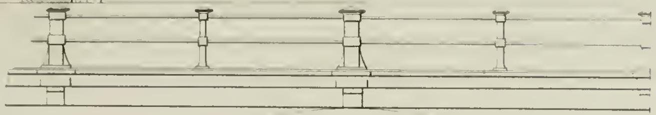


Fig 13

Fig. 17

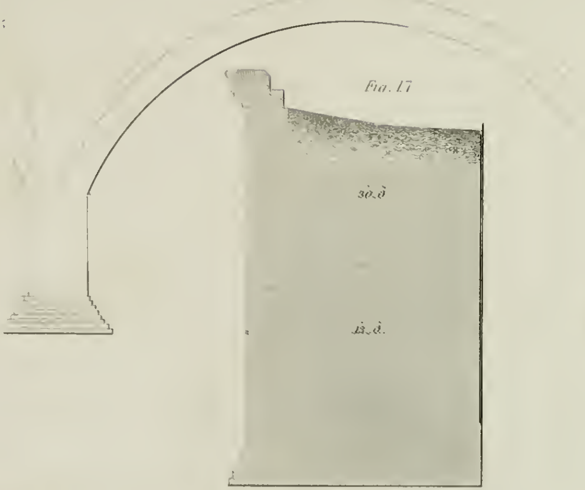


Fig 16

Fig 18.

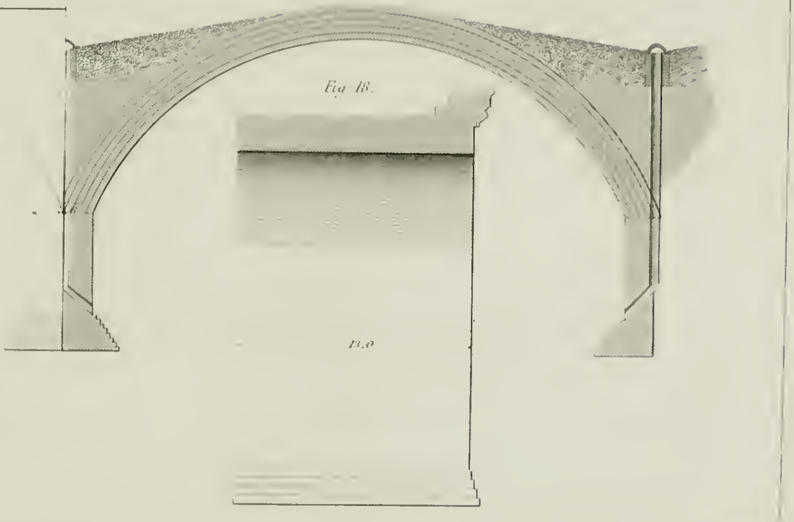


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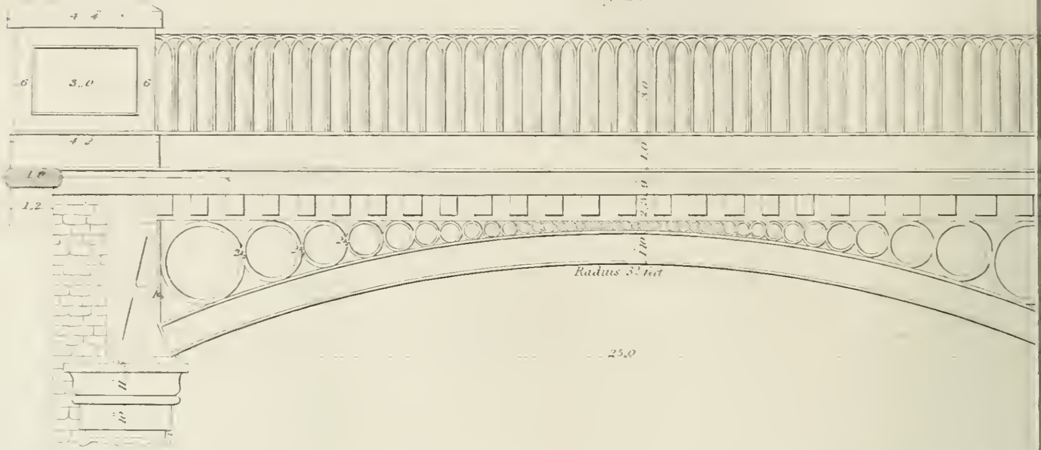
Fig. 1.



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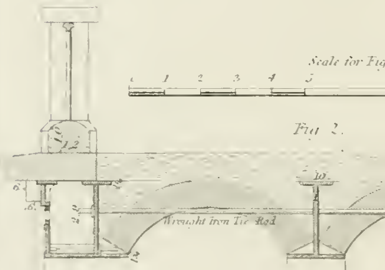

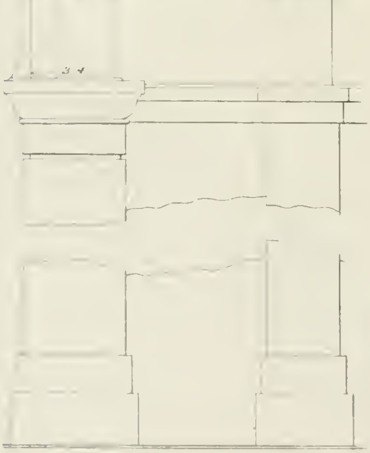

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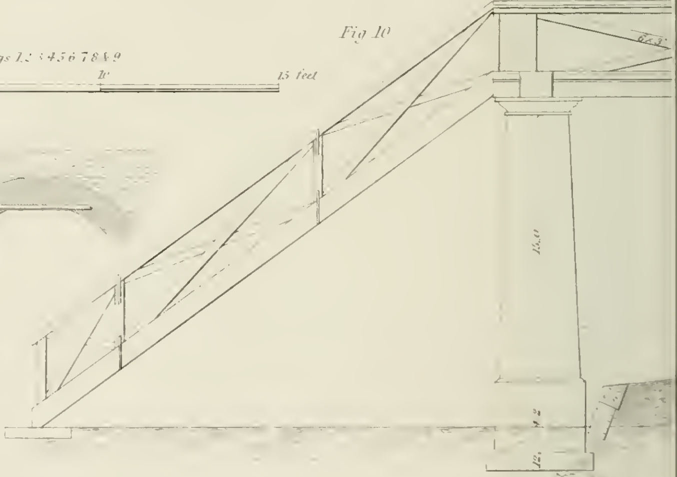

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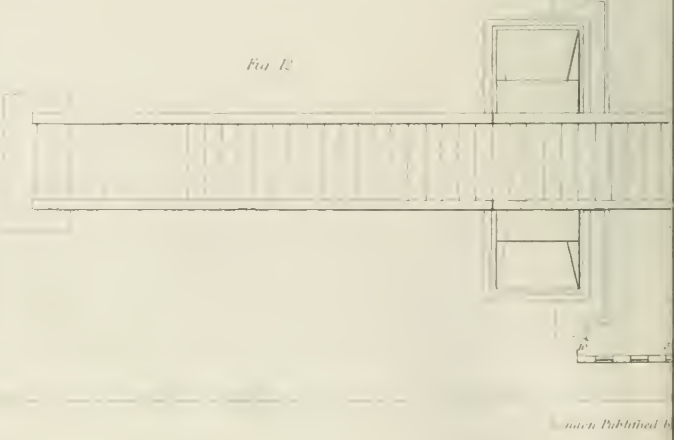

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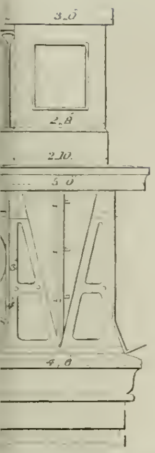

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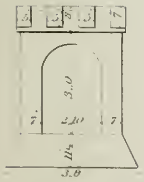

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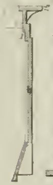

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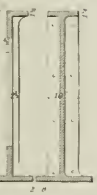

Fig 5

Fig. 4

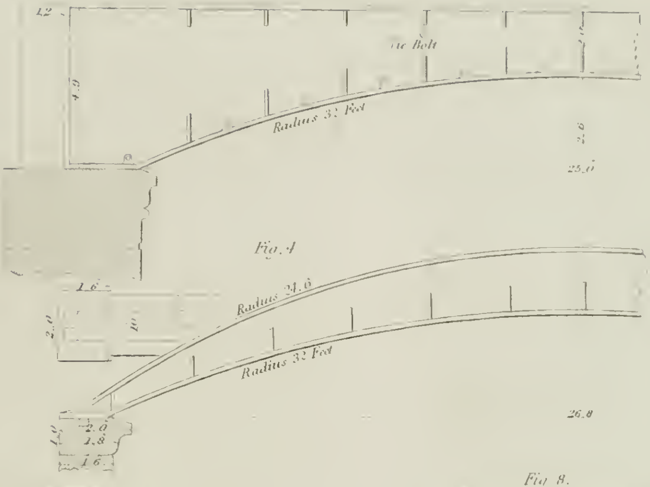

Fig 8.

Fig 9.

Fig. 11.

Fig 14

Fig 13.

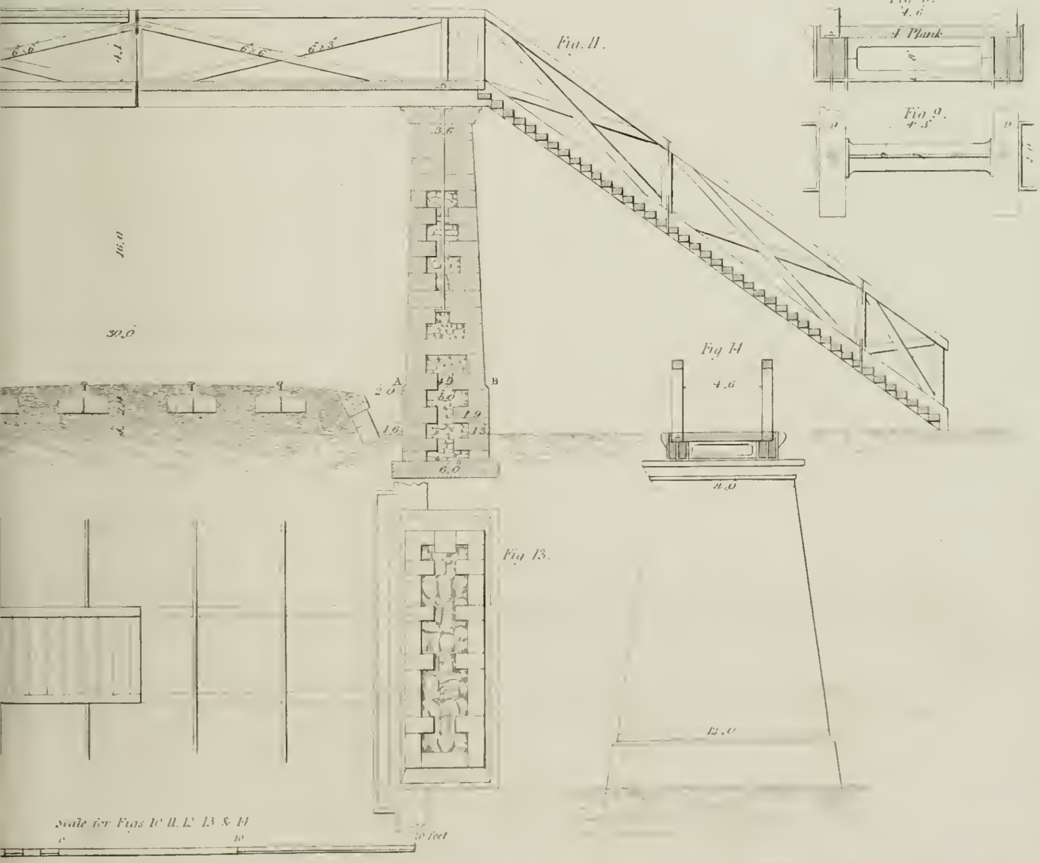

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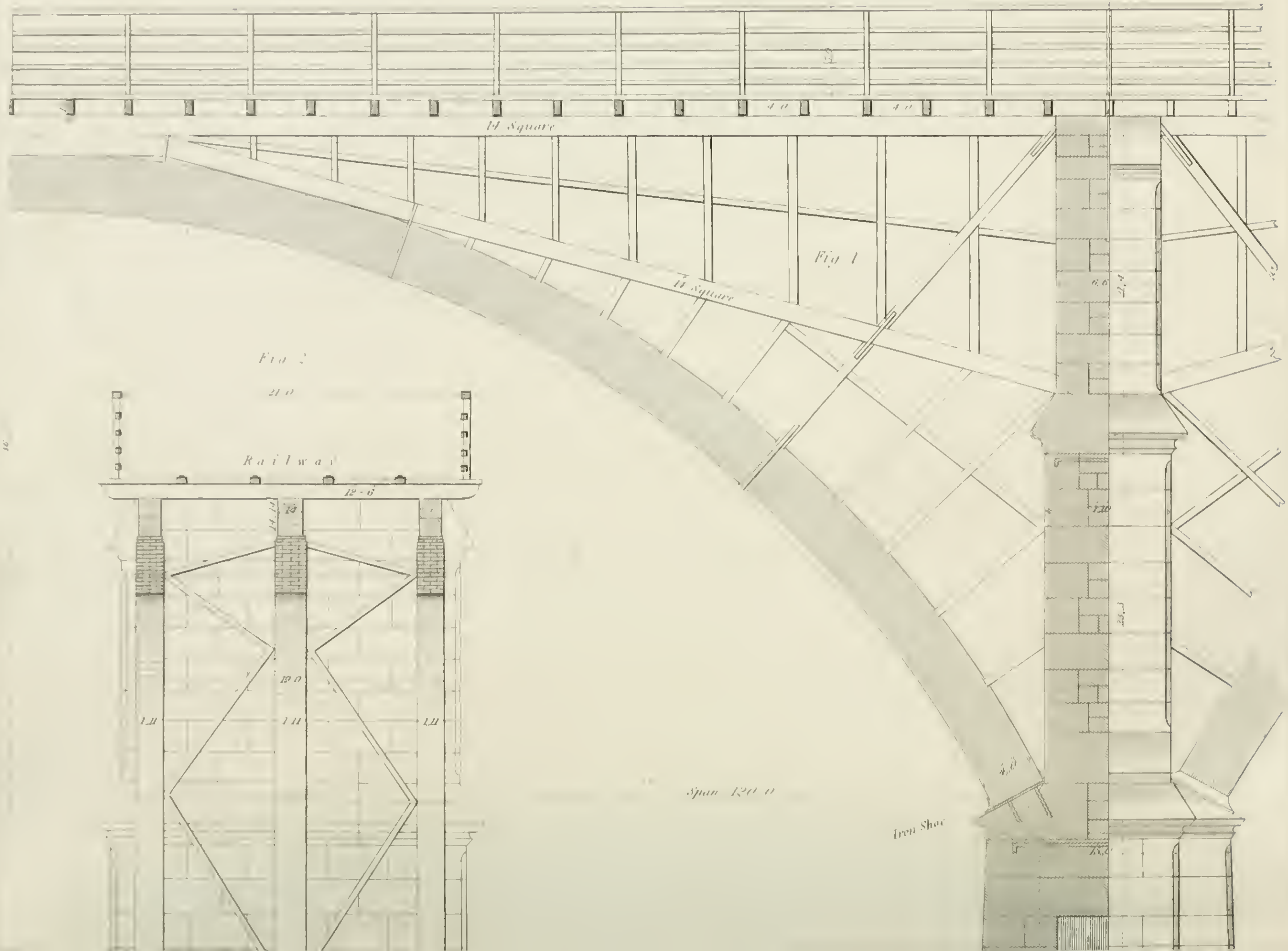
Plate 32



14 Square
4 0
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Fig 1
11 Square
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Fig 2
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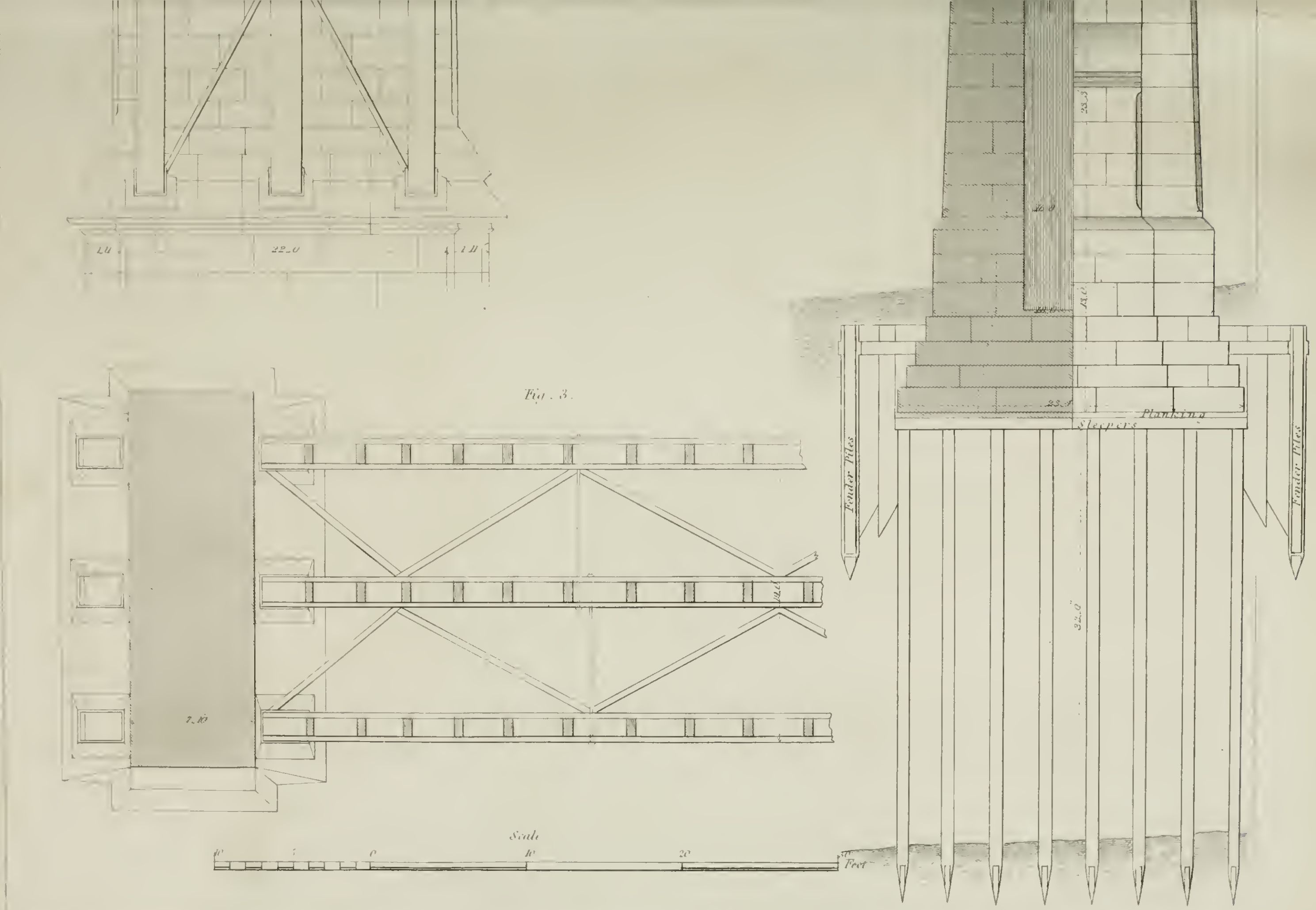

Fig. 3.

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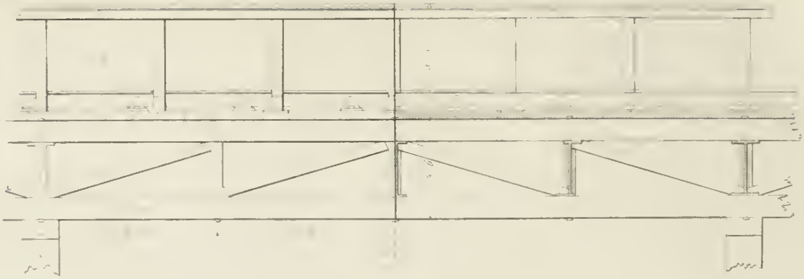
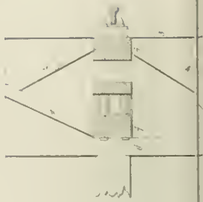
Fig 3. Fig 4.





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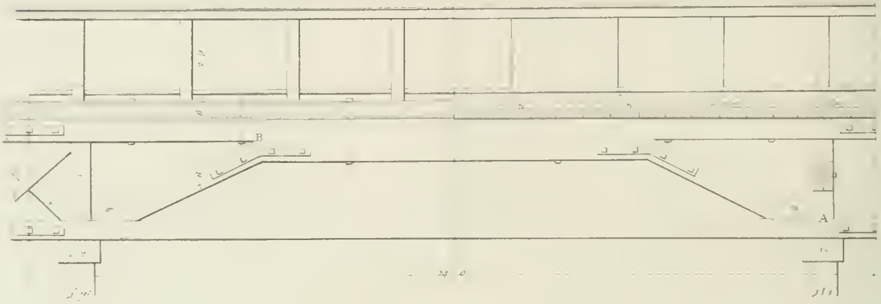

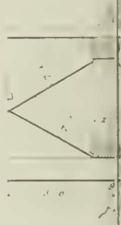

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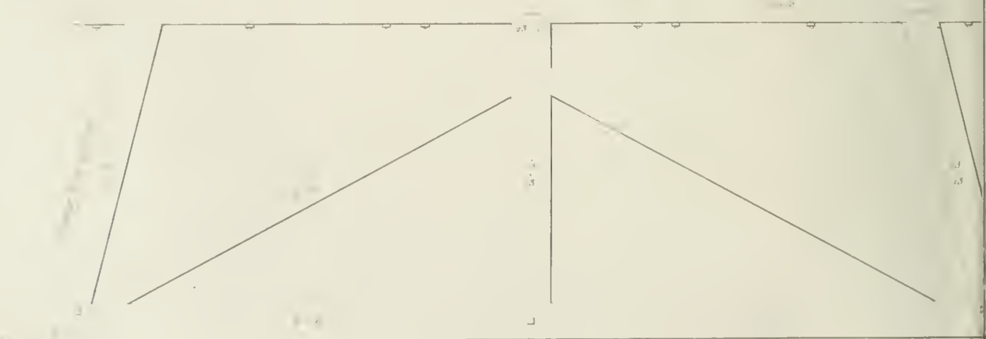

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Fig 3.

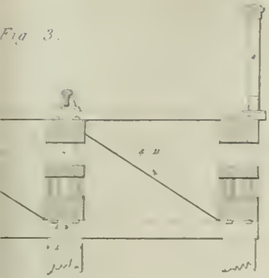


Fig 9

Fig 10

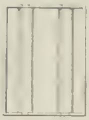


Fig 11

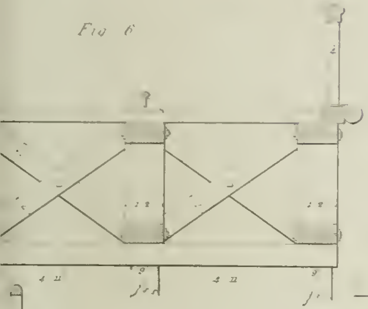
Fig 12

Fig 13

Fig 14

Fig 16

Fig 6



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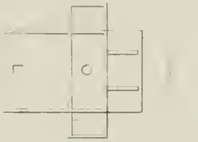

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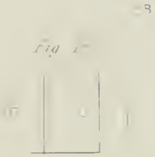

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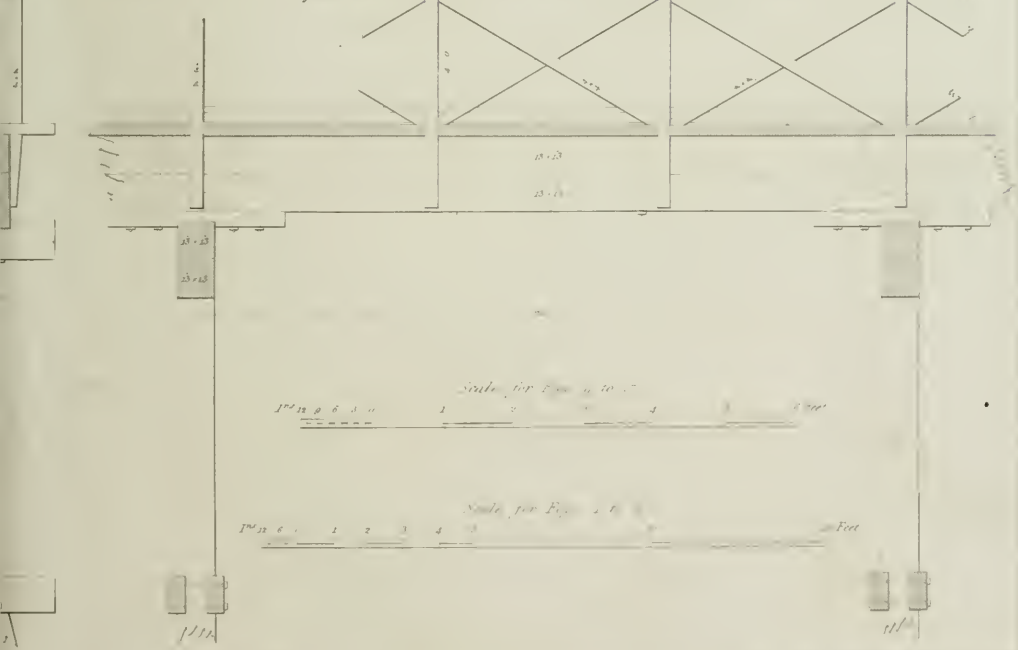

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Scale for Figs 1 to 8

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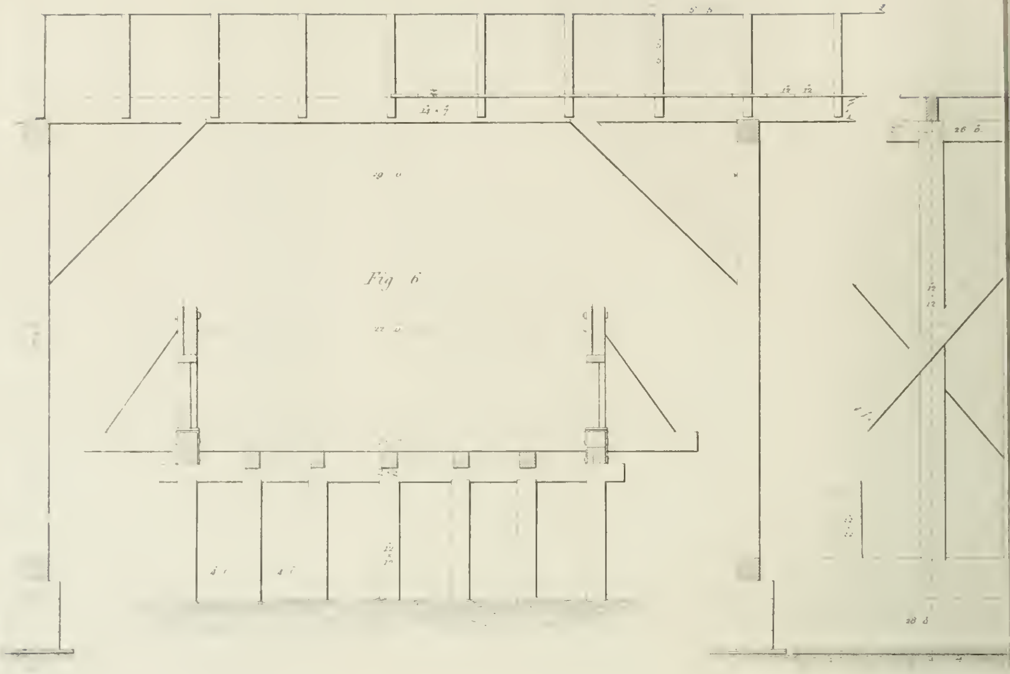
Fig. 1

Fig 6



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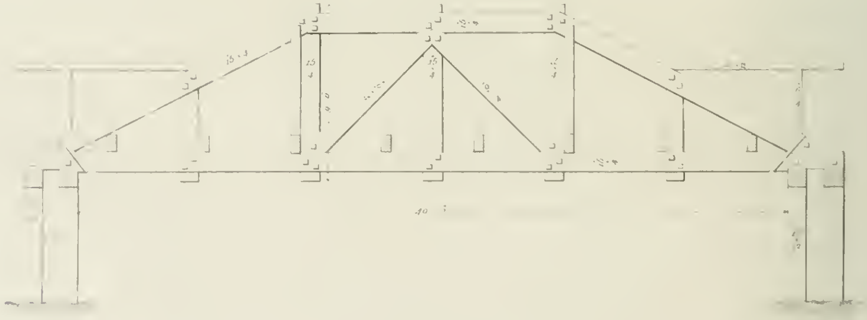

Scale for figs 1 2 3 & 4

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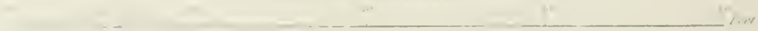

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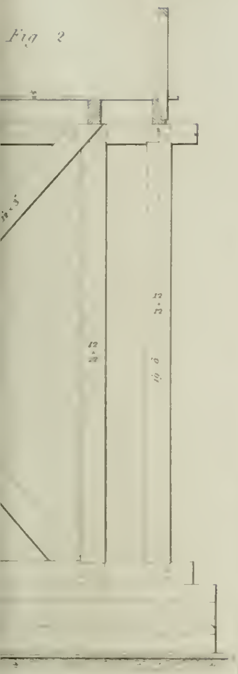

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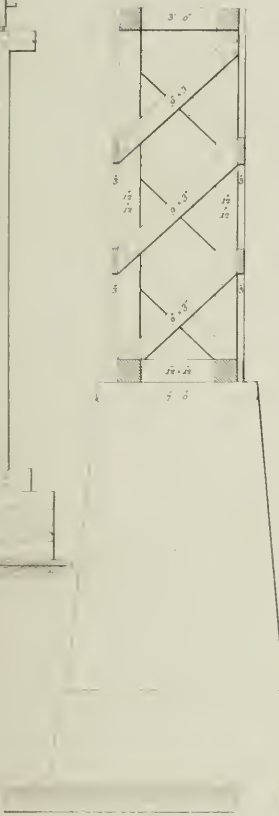

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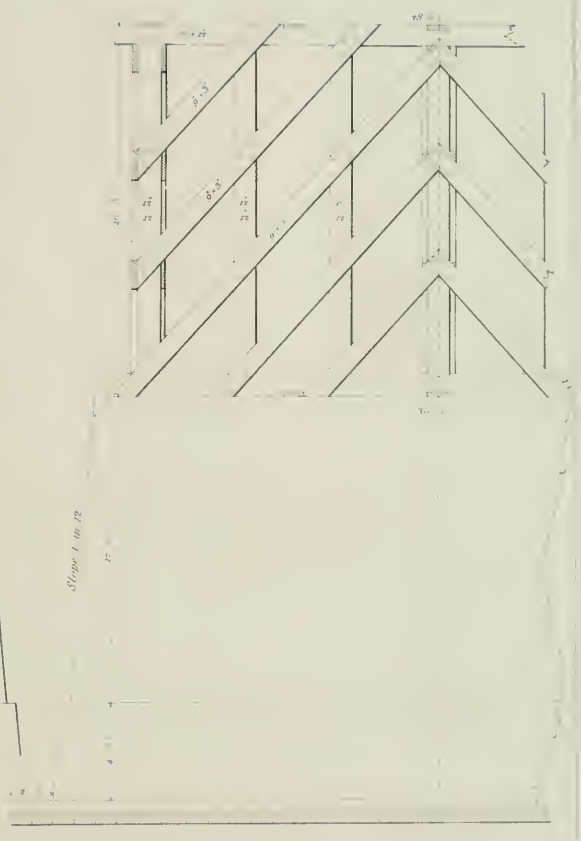

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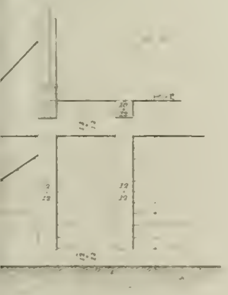

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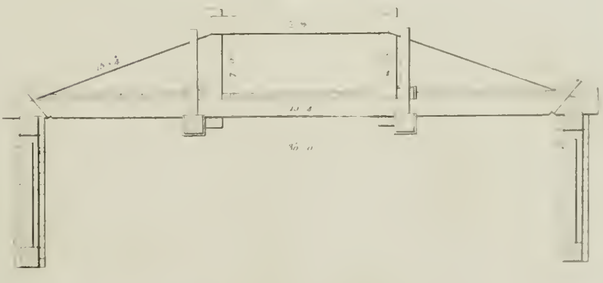

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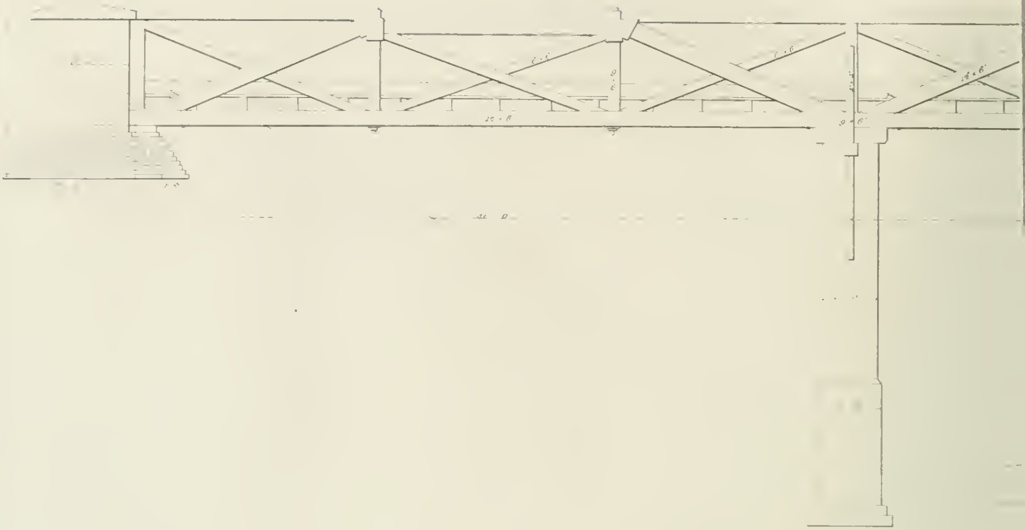

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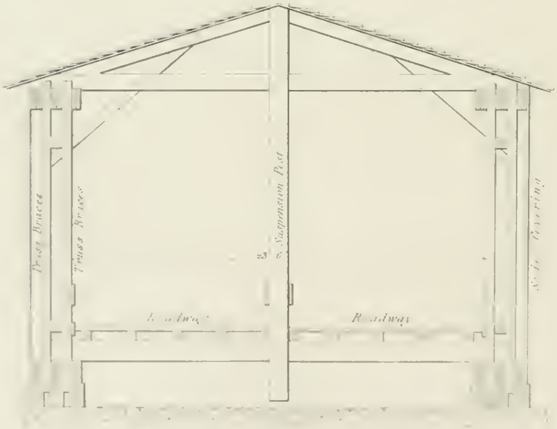

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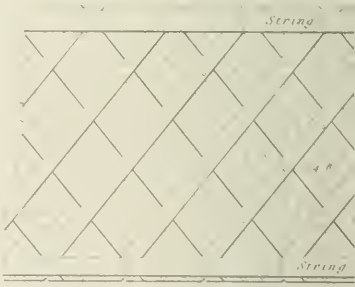

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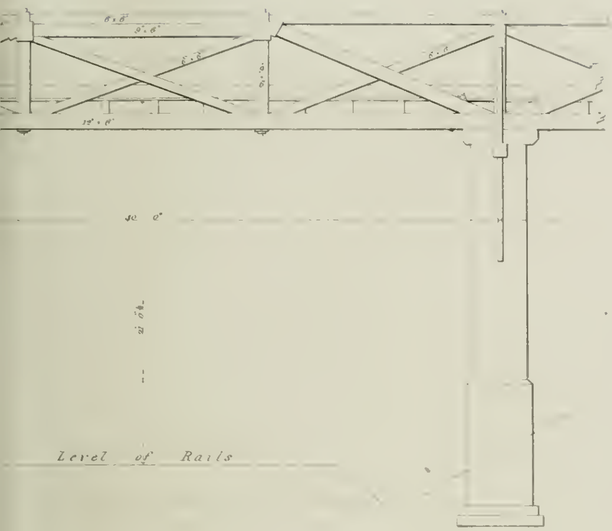

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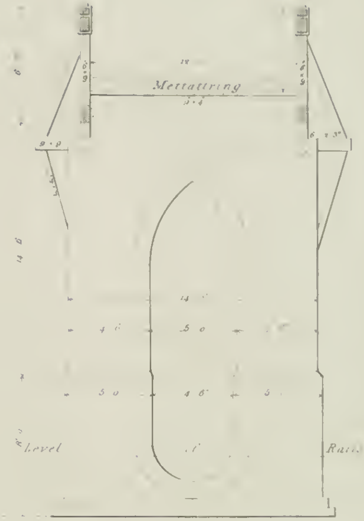

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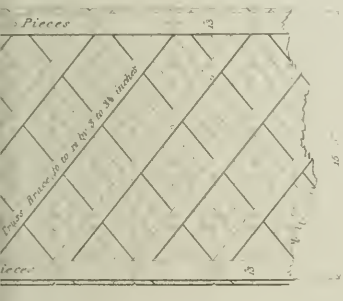

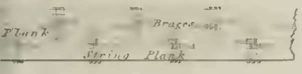

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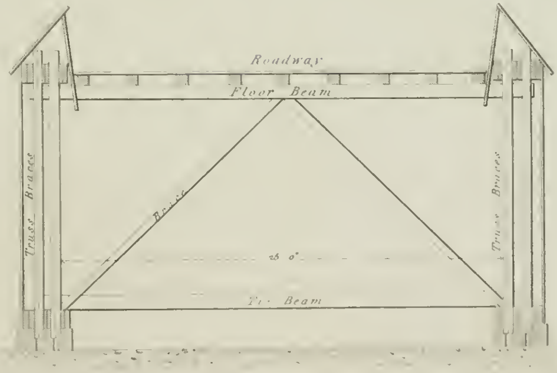

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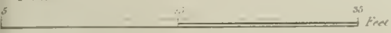

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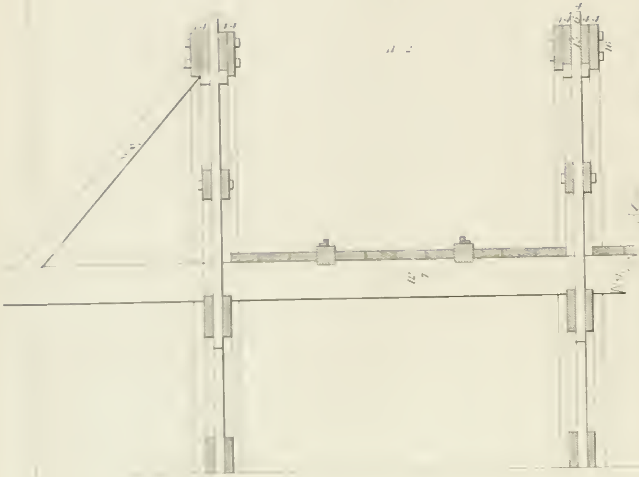
Fig.



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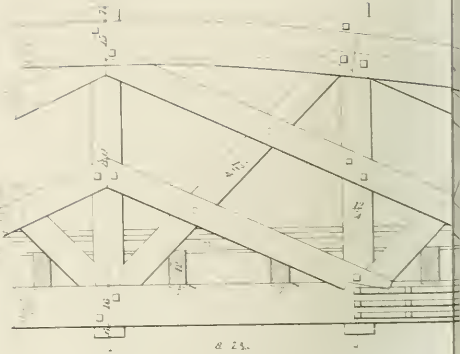

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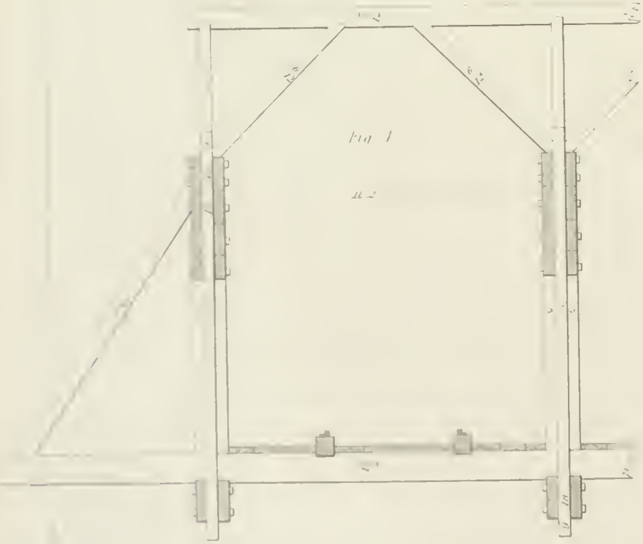
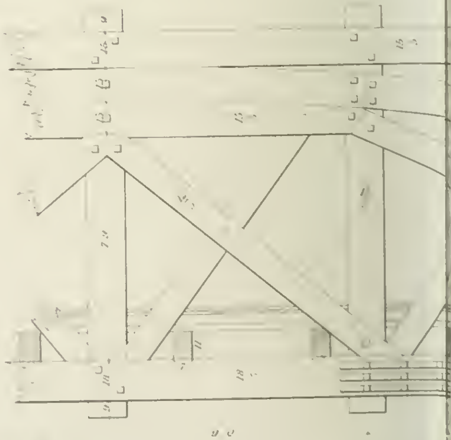


Fig 1

Fig 5



Span 74 feet

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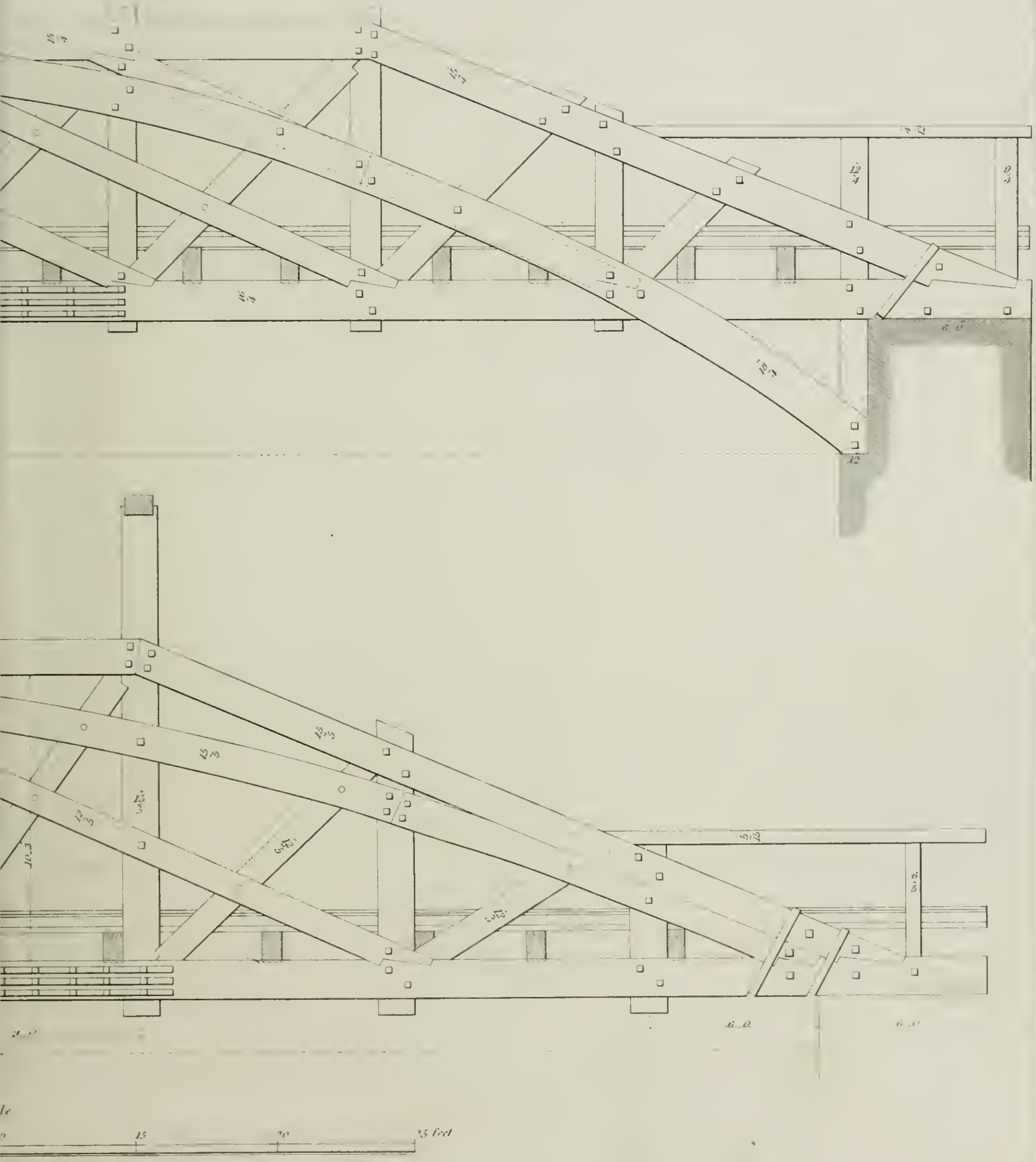

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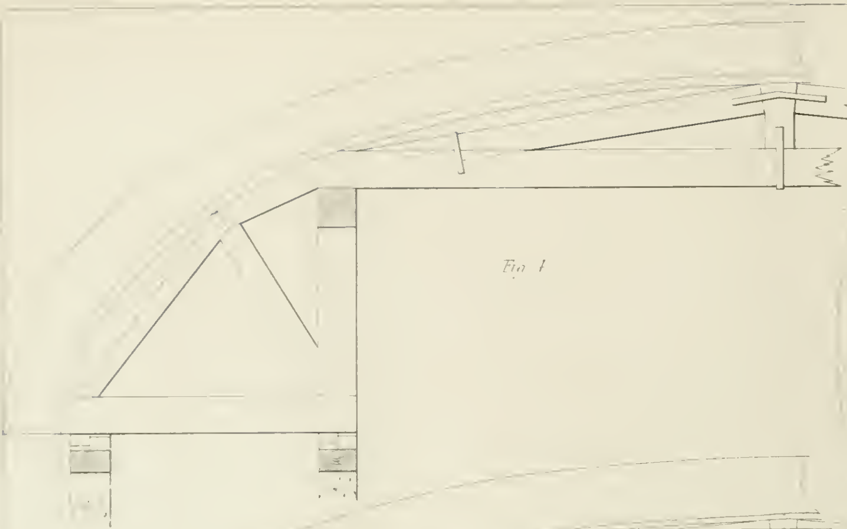

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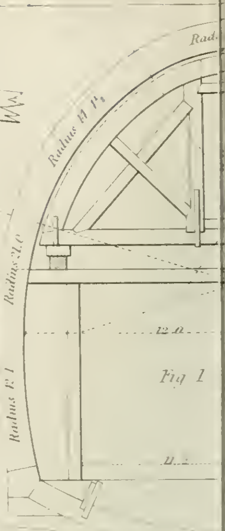

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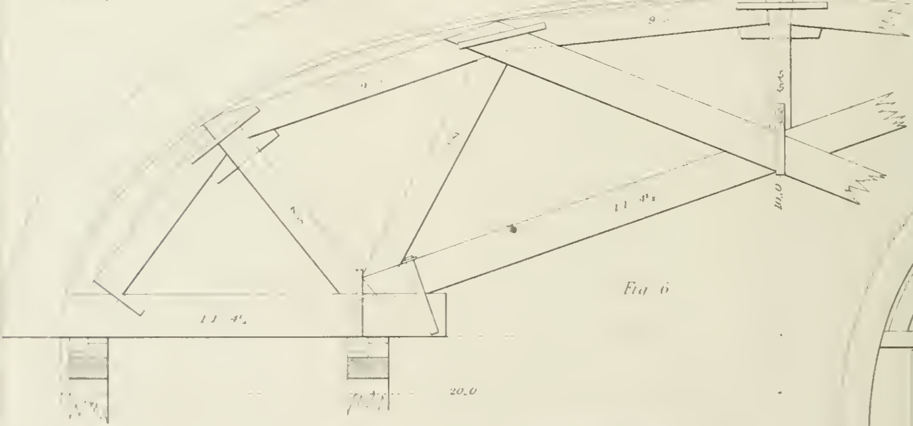

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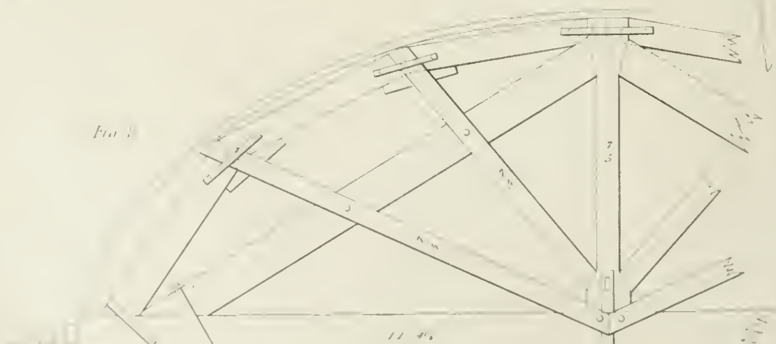

Fig. 8

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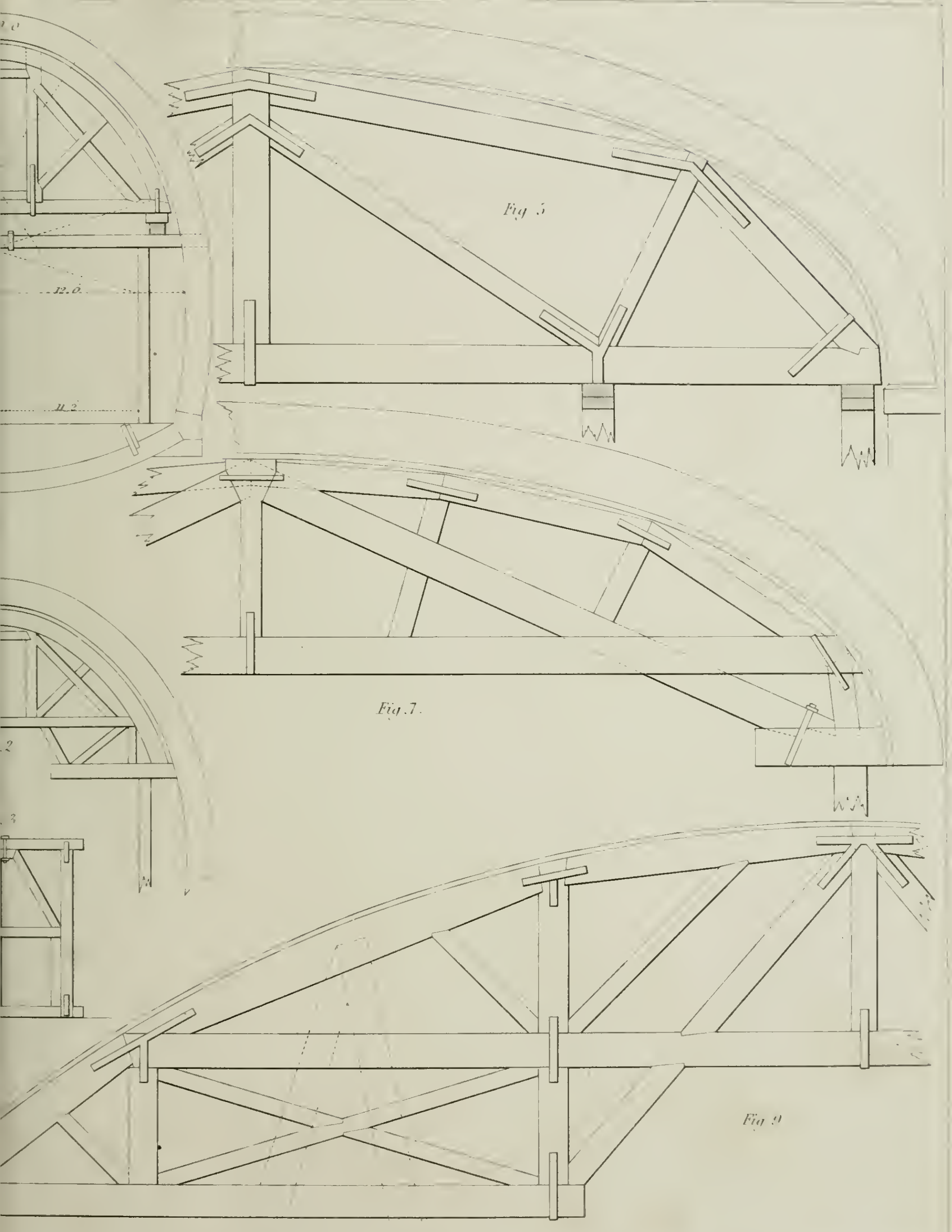

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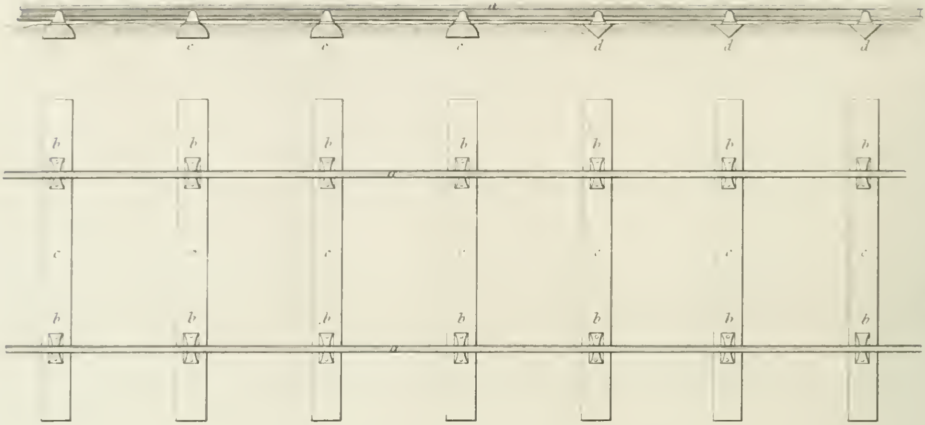
Fig. 9.



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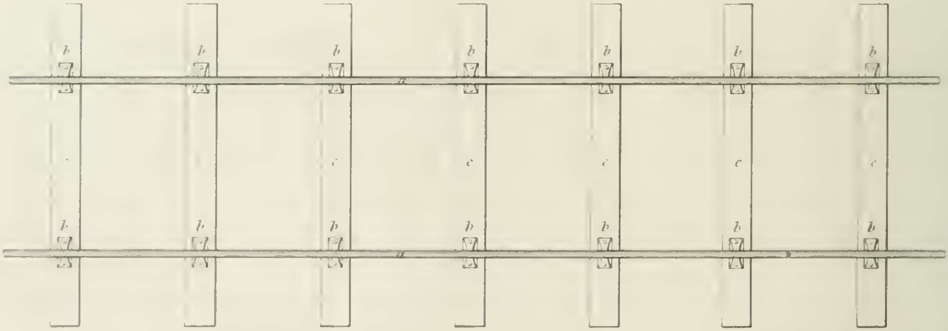

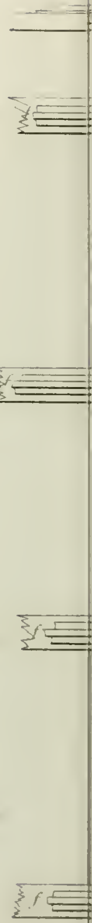

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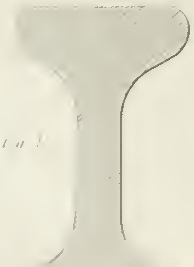

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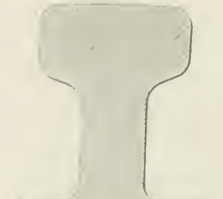

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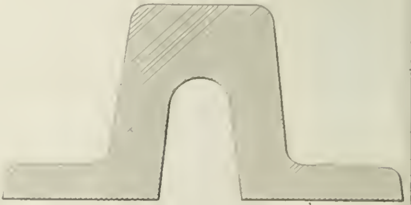

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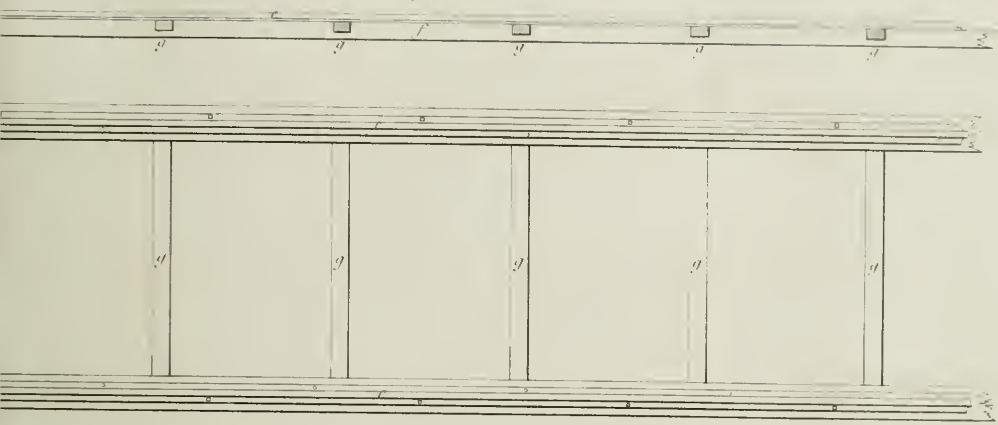

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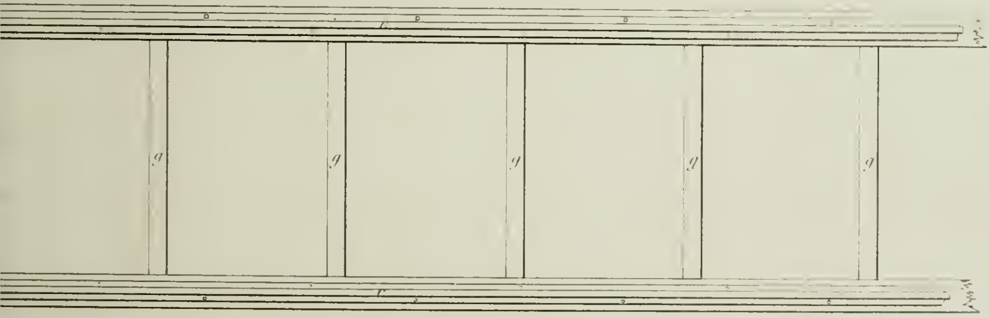

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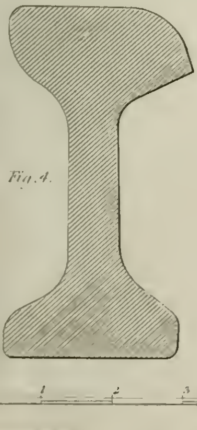

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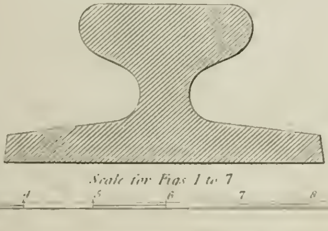

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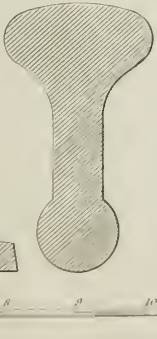

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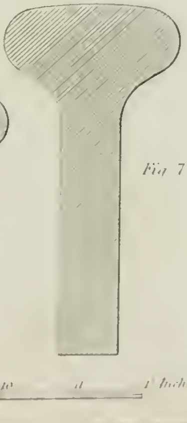

Scale for Figs 1 to 7

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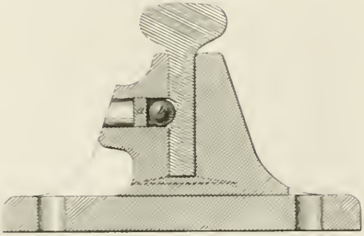
Fig. 1



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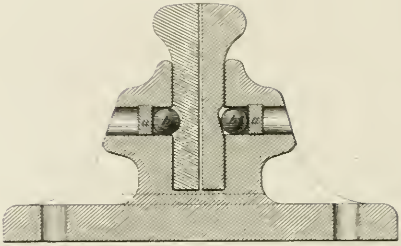

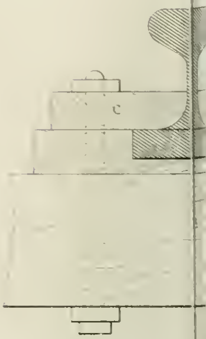

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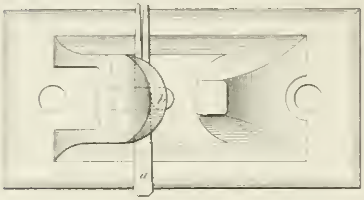

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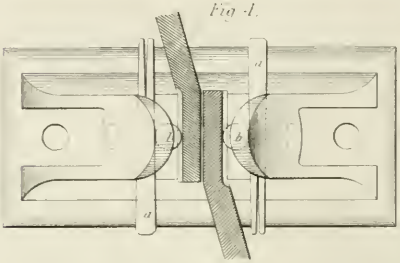

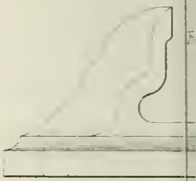

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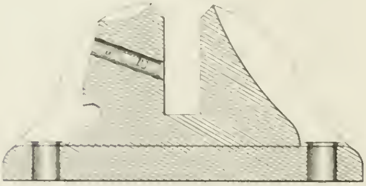

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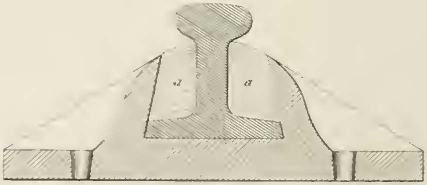

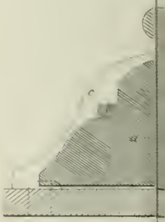

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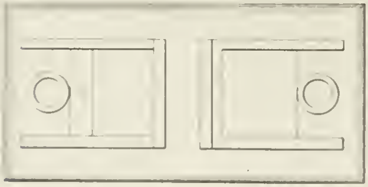

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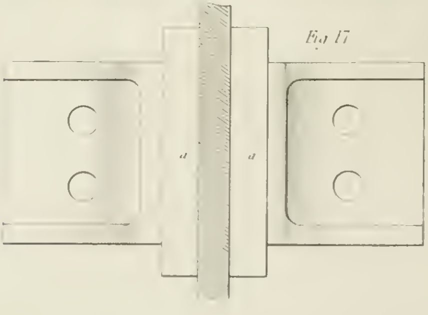

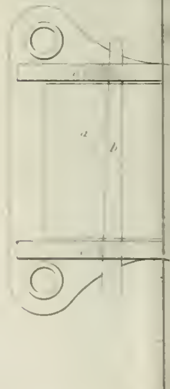

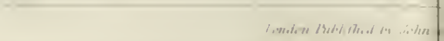

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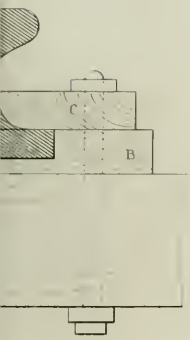

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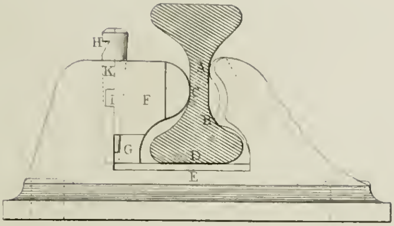

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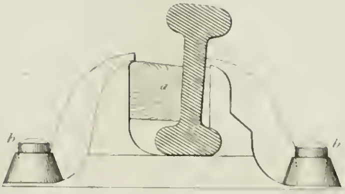

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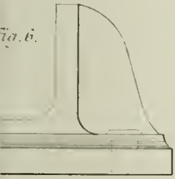

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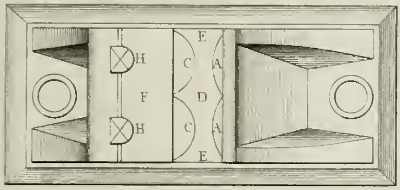

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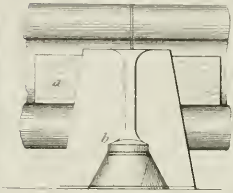

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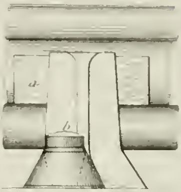

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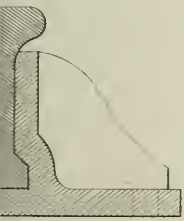

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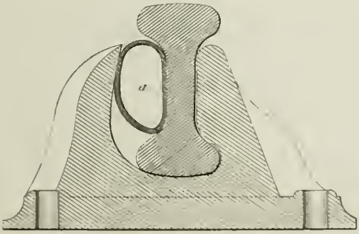

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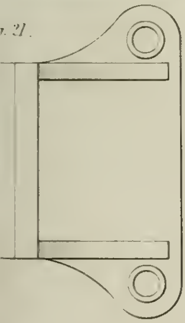

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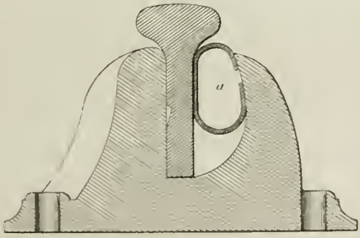

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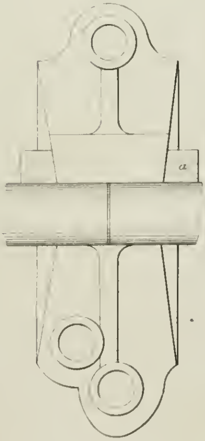

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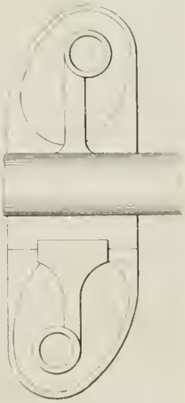

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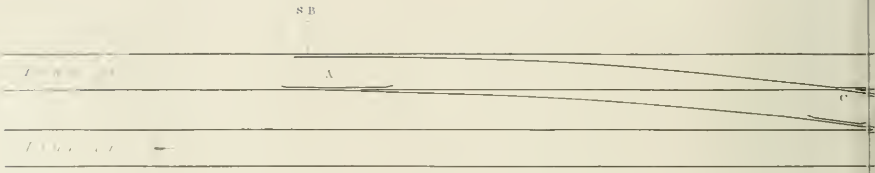
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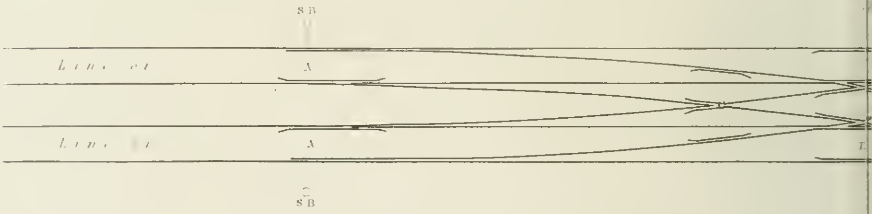
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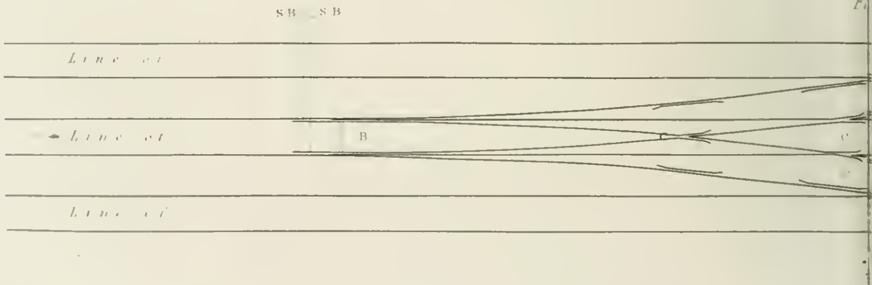
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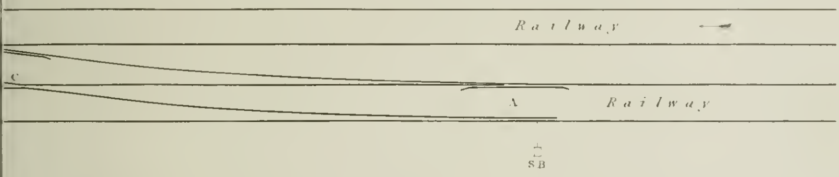

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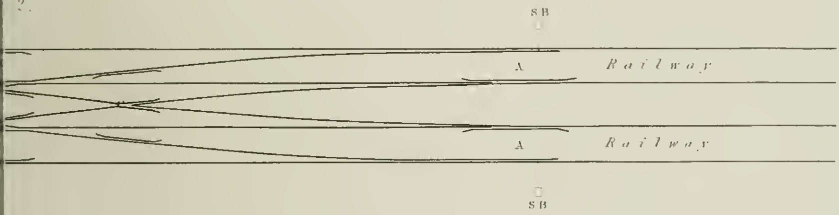

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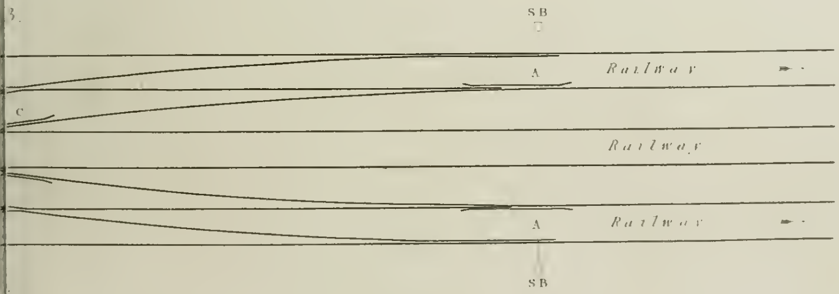

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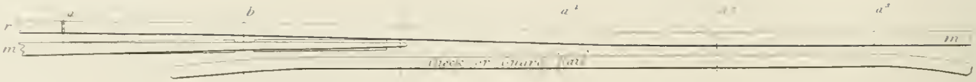
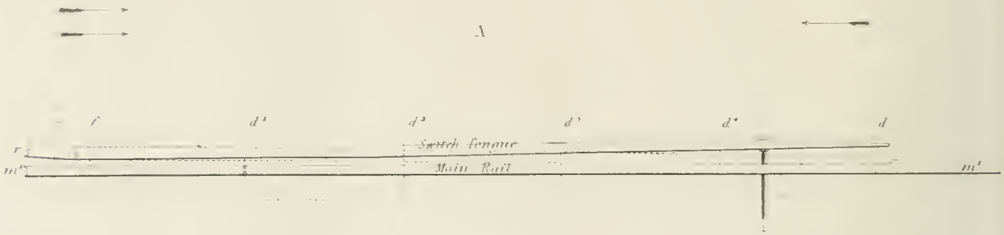
Fig. 1





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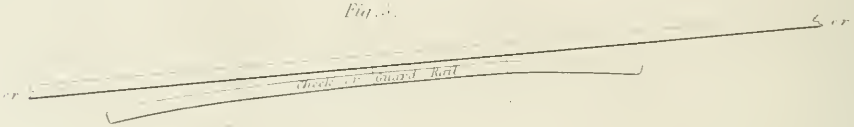

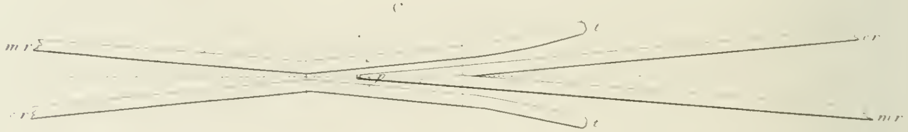

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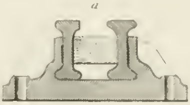

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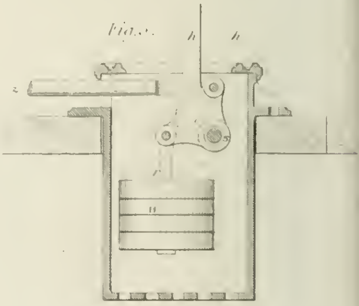

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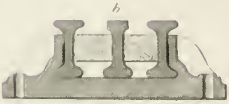

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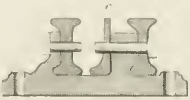

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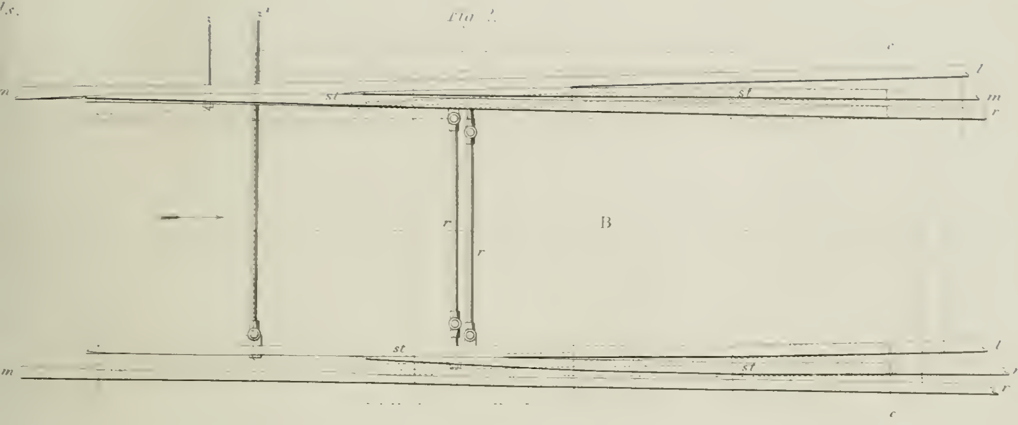
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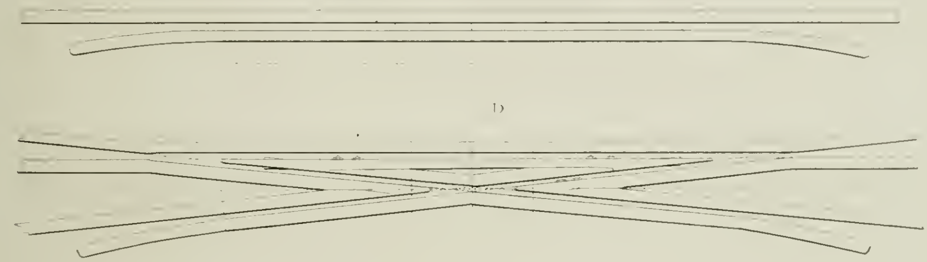

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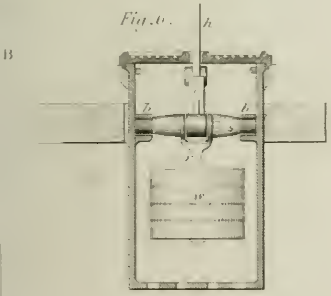

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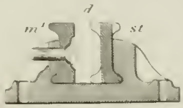

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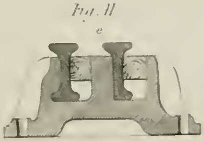

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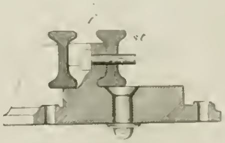

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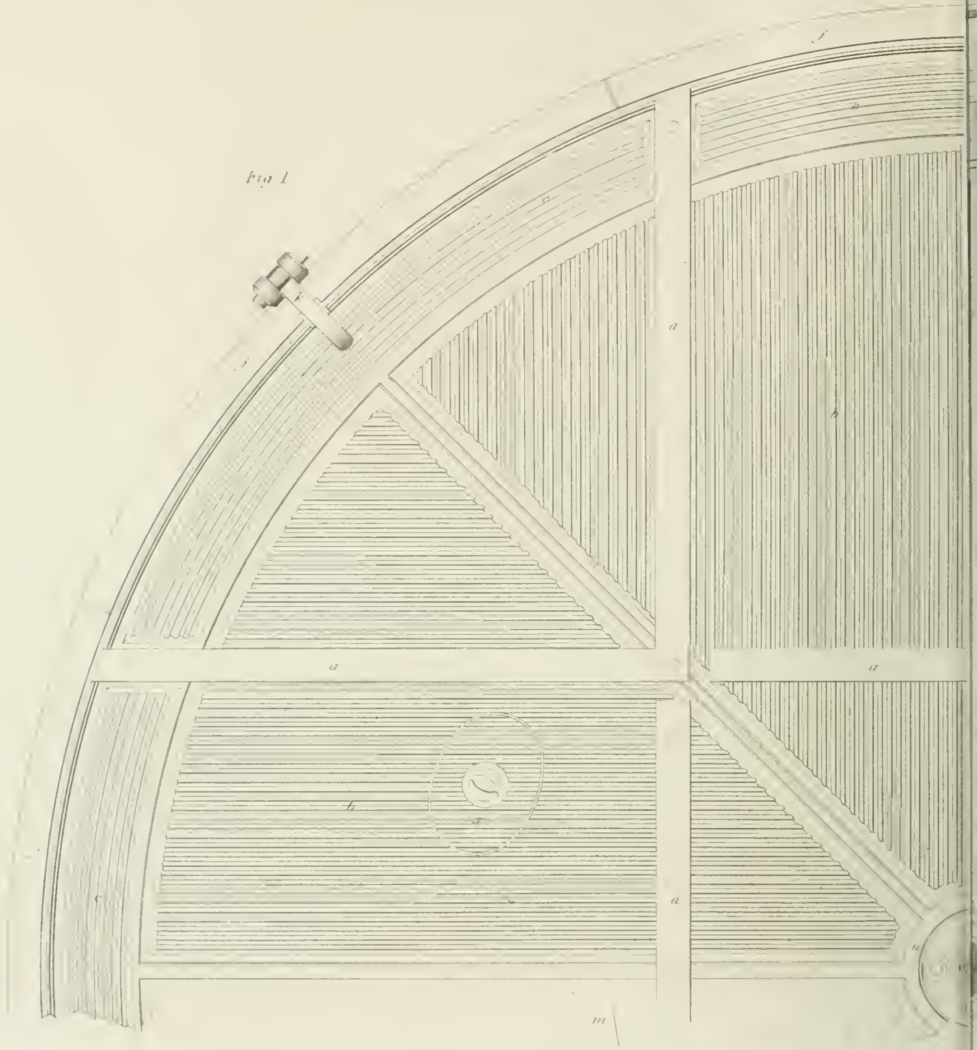
Fig 1.



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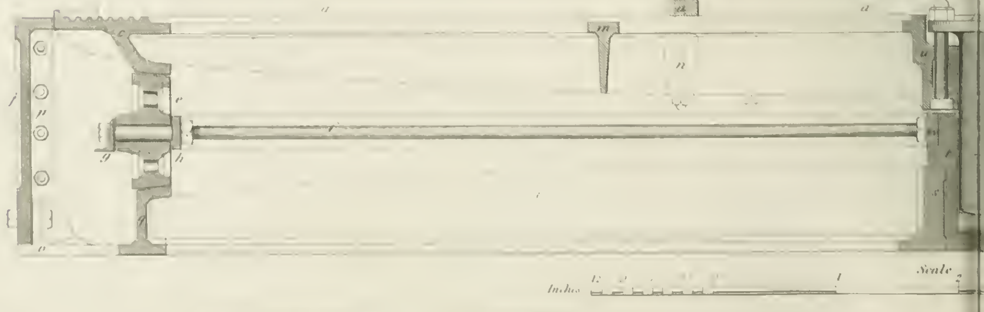

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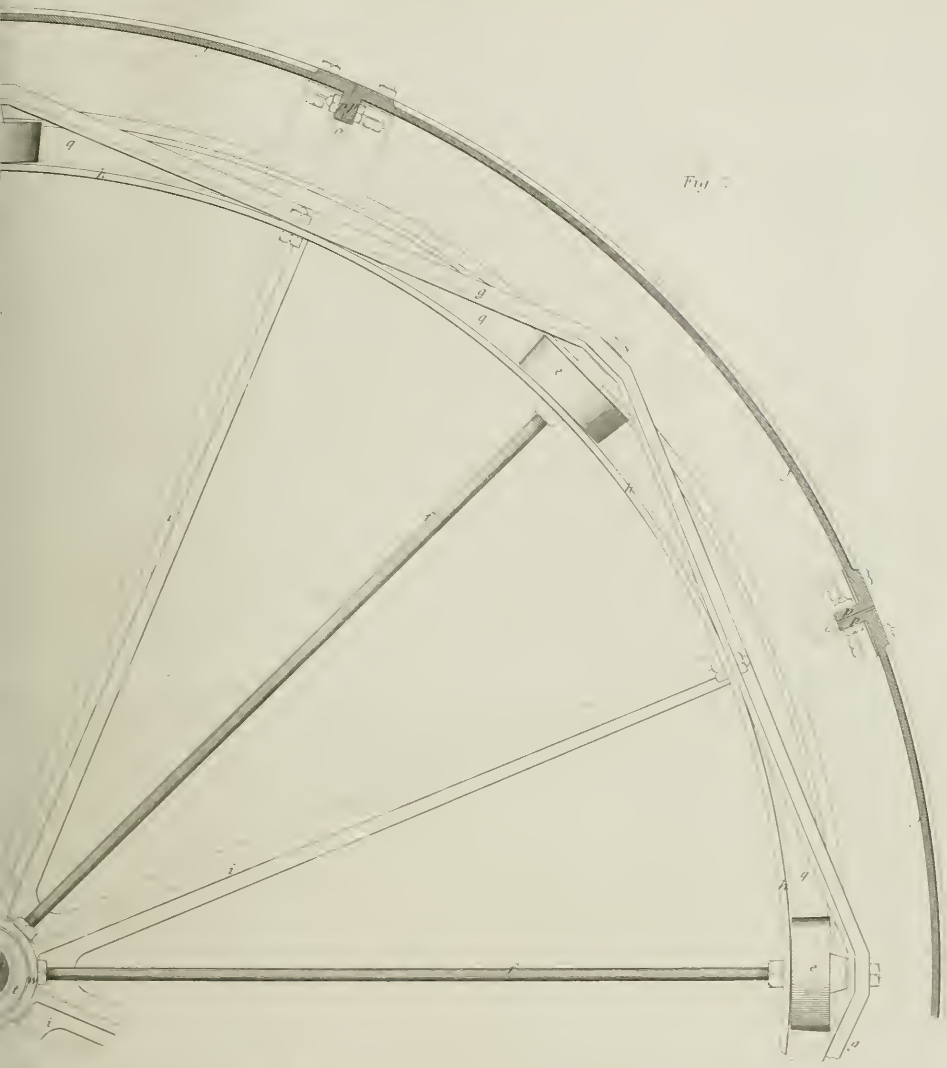

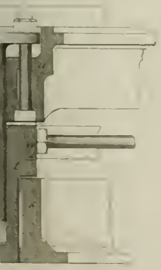

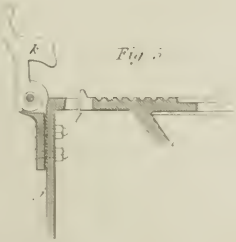

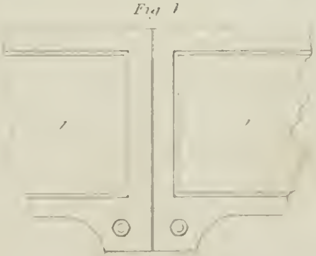

3 4 5 feet

l. 59 High Holborn 1845.

The chairs required, supposing the rails to be rolled in lengths of 15 feet each, will be 1408 joint chairs, and 7040 intermediate; and their weight, reckoning each joint chair at 20 ℔s., and each intermediate chair at 15 ℔s., will be 12 tons 11 cwt. 1 qr. 20 ℔s., and 47 tons 2 cwt. 3 qrs. 12 ℔s., respectively, or 59 tons 14 cwt. 1 qr. 4 ℔s. together.

The rails, assuming their weight at 56 ℔s. per yard, will weigh 176 tons,—1408 lengths being required.

If two oak trenails and two iron spikes be required for each chair, 16,896 of each will be wanted per mile, with 8448 wooden keys for fixing the rails in the chairs.

If felt be interposed between the chairs and sleepers, and the former be assumed at 10 × 5 inches bearing surface, 2933 square feet of felt will be required per mile.

The timber in the side fences, formed of posts 8 feet long, 6 × 4 inches, 9 feet apart, with four rails $5 \times 2\frac{1}{2}$ inches, and intermediate upright stay 3 × 2 inches, will consume as follows: 1174 posts = 1565 cubic feet; 4696 rails = 3666 cubic feet; 1174 stays = 269 cubic feet; or a total of 110 loads.

Of the masonry, timber, iron, &c., &c., in bridges, viaducts, culverts, drains, retaining walls, &c., scarcely any estimate can be formed. Taking the average of a few cases, the masonry would appear to amount to about 110,000 cubic feet per mile; but in some cases from 30 to 50 per cent. of this quantity is substituted by timber and iron.

G. D. D.

XV.—*Journal of the Practical Operations in Mining, carried on under the Glacis, in front of the left face of the Ravelin, and the right face of the Duke of Cumberland's Bastion, Chatham Lines, during the months of October and November*, 1844, *under the direction of Lieut.-Colonel Sir J. M. F. Smith, Royal Engineers, Director of the Establishment for Field Instruction.*

Plan A. THE general plan accompanying this Journal shows the disposition and extent of the countermines, as well as the state of progress of the offensive mines and trenches, on Monday the 21st of October, 1844, which, in consequence of the previous work having been performed at broken periods, may be considered, so far as regards the present Journal, as the first day of the operations.

COUNTERMINES. The countermines had been in the course of gradual construction for several months, with a view to practising the officers and men at the Royal Engineer establishment in the manual operations of sinking shafts, and driving galleries and branches; and in order to make this exercise more valuable, the galleries were arranged according to a system proposed by Lieutenant H. N. Penrice, of the Royal Engineers, a very intelligent young officer, who, by close application to the subject, had made himself conversant with the various systems described in the more modern and improved works on the art of Military Mining.

Vide Plan B. Lieutenant Penrice's system is composed of principal galleries, driven perpendicularly, or nearly so, to the counterscarp, for a distance of about 180 feet from the ditch, and at intervals of about 65 feet apart; and these are formed in a series of ascending and descending planes, so arranged with respect to each other, that when seen in vertical section the ascending plane of one gallery appears to be opposite to, or cor-

ATTACK. The earlier operations of the attack, consisting of batteries, parallels, and approaches, had been carried on in the ordinary summer instruction of the junior officers and men; and when the attack of the countermines was decided upon, Captain G. Wynne, of the Royal Engineers, was appointed to conduct it, assisted by the under-mentioned Officers of the East India Company's Engineers, viz.

ENSIGNS.

J. H. Dyas.
A. Fraser.
C. S. Paton.
H. Drummond.
J. C. Harris.
P. P. L. O'Connell.
T. G. Glover.
H. Hyde.
R. Young.
J. G. Fife.
G. Hutchinson.
G. V. Winscom.

A party of fifty-two non-commissioned officers and privates of the Royal and East India Company's Sappers and Miners were selected for the attack, and formed into brigades; and 2000 lbs. of gunpowder were allotted to Captain Wynne for the attack.

COUNTER-MINES.

respond with, the descending plane of those contiguous to it. The object of this construction is to obtain a diversity of lines of least resistance.

Lieutenant Penrice does not propose any counterscarp or transverse gallery parallel to the ditch, but the principal galleries are united by oblique galleries which are nearly horizontal.

This system of defence includes a method of lodging large charges of gunpowder, at a distance of from 12 to 15 feet, from the ends of the galleries or branches.

The suggestion is, I believe, quite new, and the mode of carrying it out is clever, but further experience and improvements are necessary to render the arrangement perfect and safe.[1]

DEFENCE.

When the attack was commenced, Lieutenant Penrice was directed to conduct the defence, and 1000 lbs. of gunpowder were placed at his disposal. The Officers of Royal Engineers appointed to assist him, and to take charge of the several reliefs, were as follow, viz.

LIEUTENANTS.

C. S. Hutchinson.
H. Wray.
C. Pasley.
J. Stokes.
W. R. G. Hickey.
A. Clarke.
F. Du Cane.
R. D. Kerr.
J. Y. Moggridge.
F. Koe.

A party of eighty non-commissioned officers and privates of the Royal and East India Company's Sappers and Miners was told off for the defence, and formed into brigades.

ATTACK.

With a view to render the operations more instructive to the officers and men, precautions were taken to prevent either party being in any way acquainted with the general plan, or the details of the intended measures of their opponents; and with this object they were kept perfectly distinct from each other, and both officers and men abstained scrupulously from giving any information to those opposed to them. The greatest zeal and emulation were observable on either side, and the operations were as nearly as possible assimilated to those which would be carried on in the attack or defence of an enemy's fortress.

Each party had its own magazine, stores, implements, and mining frames, so that in every respect they worked independently of each other; but in order that the whole of the works might be accurately laid down, both above and below ground, and embraced in general plans, they were surveyed daily under the orders of Captain J. Williams, of the Royal Engineers, and the operations of the 24 hours were plotted on drawings, which were kept by him under lock and key, and to which no one had access but himself, the Director of the Institution, Lieut.-Colonel Sir Frederic Smith, and the Adjutant, Captain G. Whitmore, of the Royal Engineers. Captain Williams also kept a journal of the defence, and analyzed and arranged the Reports of the Executive Officers employed on both sides; to which Captain Wynne added such details and information as had not been embraced by the junior officers of his division.

In the month of September, Captain Wynne had pushed forward three galleries from the third parallel.

The right gallery (w) being 11 feet in length.
The centre do. (x) ,, 23 ,,
The left do. (y) ,, 12 ,,

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[1] Lieutenant Penrice's description of his invention will be found in the Appendix to this Journal.

Defence.
1844.
21st Oct.
1st day of Defence of Counter-mines.

The miners were employed in preparing a chamber at the end of the central gallery (C) for the reception of a charge, the operation being conducted in the following manner.

A hole, 12 feet long, was drilled with a 3-inch bit, and a charge of 3 ℔s. of gunpowder was inserted.[2] On this charge being fired, the explosion was sensibly felt on the surface, at a distance of even 250 feet from the spot. On the gallery being visited immediately afterwards, it was found to contain very little smoke.

The form or capacity of the chamber produced by this fougasse could not of course be determined; but judging from previous experiments, it was assumed that it would be sufficiently large to contain from 90 to 100 ℔s. of powder.

The chamber would have been immediately loaded, but it was found that the oakum which encircled the tamping bar had fixed it so tightly to the sides of the cylindrical hole, that considerable force was necessary to extract the bar, and required so much time, that before it could be effected the hour had arrived for discontinuing the work for the day; and moreover, arrangements had not then been made for employing the men beyond the ordinary working hours.

22nd Oct.
2nd day.

It was considered that in loading at the end of so long a gallery, it would be proper to light the gallery with safety lamps, and as there had never been any belonging to the establishment for the use of the miners, several hours were lost this morning before they were procured. They were at length borrowed from the dock-yard and the observatory, and at ½ past 11 o'clock the charge, amounting to 90 ℔s., made up into cartridges of 1 ℔. each, in cylindrical flannel bags,[3] 2¾ inches in diameter, was conveyed to the head of the centre gallery (*C* 1).

Attack.
1844.
21st Oct.
1st day of Attack of Counter-mines.

The garrison were heard working in a direction as if passing to the right of the centre gallery (*x*). A branch was commenced, and preparations made for springing a mine of 300 ℔s., in order to blow up the head of the countermine gallery. A chamber was made to receive three boxes, each containing 100 ℔s., and every thing was ready for loading, when, after reference to the general plan, the Director expressed it as his opinion, that although this charge might damage the countermine gallery, in the way intended by Captain Wynne, yet that it would injure his own battery. Captain Wynne therefore determined to lengthen his gallery before he fired.

Two frames were also set in the right gallery (*w*).

Late in the evening, in the left gallery (*y*), a drift was commenced by boring with a 7-inch bit; this mode of operation having been adopted from an impression that one of the countermine galleries was at no great distance, and that as the miners of the garrison were supposed to be preparing a charge, it was right, if possible, to anticipate them.

22nd Oct.
2nd day.

In the right gallery (*w*), the miners advanced 10 feet, with close casing; and in the centre gallery (*x*) 9 feet. In the left gallery (*y*), the drift was extended 19 feet by the boring bit.

A large party of workmen was employed in clearing away the mud from the trenches, and protecting the mouths of the galleries, by means of a lean-to of baulks and chesses, resting against the interior slope of the parallel and the sole of the trench.

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[2] For the mode of operation, vide Appendix.

[3] Some of the cartridges had previously been covered with paper, and some with flannel, but it became necessary to discontinue the use of the paper, as it broke, and spilt the powder.

DEFENCE.

22nd Oct.
2nd day.

Some further delay then occurred in placing in the cylindrical hole a copper pipe, through which the charge was to be passed into the chamber, and it was 1 o'clock before the first cartridge was lodged in it.

By 3 o'clock the loading was completed, the whole of the charge having been passed through the tube.

The tamping was then commenced, and was completed in 40 minutes. The cylindrical hole was, as before, tamped by an iron bar, tightly wedged in. To this, an addition was made of 6 feet of earth; and to give still greater resistance in the direction of the tamping, two wooden stanchions were nailed transversely across the gallery. It is to be observed, that the whole length of the tamping, including the bar, was only equal to the length of the line of least resistance, viz., 20 feet.

Character of Mine No. I.

The charge was 90 lbs.

The distance below the surface of the glacis 21 feet.

The mine was fired vertically under an angle of the parapet of an offensive half-sunken battery, and was nearer in a direct line to the platforms than to the surface of the natural ground; the former was, therefore, the point of least resistance, the distance being 20 feet. The defenders distinctly heard the miners of the assailants at work, and were under an impression that the galleries of the latter were much closer to them than was actually the case. The general plan, however, in the hands of Captain Williams, showed that the defenders' charge was 24 feet distant from, and 3 feet lower, than the sole of the head of the offensive central gallery (C).

Effect of the Mine No. I.

From the smallness of the charge, in reference to the line of least resistance, no crater or surface effect was expected; a small crater, however, was produced, but not at the point of least resistance. This may be accounted for by the fact, that the tenacity of the soil around the line of least resistance more than compensated for the increased length in other directions, where it appears that the ground had

ATTACK.

22nd Oct.
2nd day.

The effect of the mine fired by the besieged was imperceptible on the attacking gallery, not a frame of which was shaken, nor was the efficiency of the battery in any way impaired. A considerable quantity of smoke was seen to issue from the parapet, which must have escaped through fissures in the ground.

Defence.

22nd Oct. 2nd day.

been disturbed by former explosions. The head of the countermine gallery adjoining the tamping was uninjured, and so free from smoke, as to offer no impediment to the immediate employment of the miners.[4]

Attack.

From this day the miners worked in three reliefs, beginning at 6 in the morning, and leaving off at midnight, each party working six hours.

The officers also were employed in reliefs, and exchanged duties two hours before the men, which was found a better system than changing the whole together, as it kept up the chain of information.

This was general to both the opposing parties.

2nd day, continued.

The miners lengthened the branch (C 1) 10 feet, and suspecting that the mine of the previous day had not done much injury to the assailants, (who, they imagined, would advance in that direction,) they removed the old tamping, with the view of making the same chamber available for another explosion.

23rd Oct. 3rd day, continued.

The driving of the three galleries was continued.

As the boring rods were not sufficiently long to admit of the work being pushed further by workmen stationed at the end of the cased gallery, the advanced end of the drift was enlarged sufficiently to receive a workman, who resumed the boring of the drift in gallery (y). The enlarging of the drift was performed with a small curved spade, and the earth was drawn out from the cylinder by means of a broad hoe.

The compass bearing of the centre gallery (x) was 38° 30′ west of the south. By 10 o'clock A.M. it had been driven in this line 14 feet, whence it had diverged to the right, for a short distance, with the sole inclined downwards, till it reached a level, 3 feet lower, to obtain a greater line of least resistance. The whole progress this day was 15 feet. Captain Wynne had altered the direction, in consequence of hearing the besieged miners at work, and hoping to meet them by the change.

The right gallery (w) had advanced 26 feet by 10 o'clock A.M., and on leaving off work, 30 feet; and its bearing was 20° west of south.

The left gallery (y) had not advanced above 2 or 3 feet by the drift.[5]

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[4] This would not have been the case if the charge had been lodged at the end of a branch, formed in the usual manner. In this respect, Lieutenant Penrice's system of loading and tamping has therefore a decided superiority over the ordinary method.

[5] The difference between Captain Wynne's and Lieutenant Penrice's system of boring, is, that the former uses a 7-inch bit, and the latter, one of only 3 inches. Captain Wynne enlarges his bore sufficiently to allow

DEFENCE.

24th Oct. 4th day.

The untamping of the first mine was continued.

Gallery *C* 1 was driven 9 feet.

At the end of gallery *C* 2, a boring was commenced, to be ready for the assailants, who, being heard, were supposed to be advancing in that direction.

25th Oct. 5th day.

Gallery *C* 2 was pushed on, and galleries *C* and *C* 1 were cleared of rubbish, and the frames strengthened by struts.

The assailants being heard from the head of gallery *C* 2, every endeavour was made to advance it, with the view of boring towards them, and discovering their charge.

The countermine galleries were not in the slightest degree shaken or injured by the explosion of the besiegers' mine No. II.

The direction of gallery *C* 2 was changed, 30° towards the east, with the view to take the attack in reverse.

The operations were carried on till midnight,

ATTACK.

24th Oct. 4th day.

Drift in the left gallery (*y*) advanced 2 feet. A chamber formed to the right, 4 feet cube. Total length of drift in a direct line 26 feet.

Centre gallery (*x*) advanced 3 feet. Total length 48 feet. A chamber formed, 4 feet cube.

Right gallery (*w*) advanced 10 feet. Total length 40 feet.

This morning, a double sap was commenced at the right extremity of the parallel, and at the time of leaving off work, it was 75 feet in advance of the parallel.

25th Oct. 5th day. Mine No. II.

The chamber in the left gallery (*y*) was loaded with 300 ℔s. of powder. From the smallness of the drift, which was only 2 feet in diameter, considerable difficulty was experienced in passing the charge, which was contained in three boxes, each of 100 ℔s.

The tamping was formed of half-dried mud, moulded into the shape of bricks, and was completed to the extent of 25 feet in 2 hours and 48 minutes. It was at first attempted to use filled sand-bags[6] for the tamping, but their weight rendered the work very laborious, tedious, and almost impracticable.

Character of Mine No. II.

The charge was 300 ℔s.

The line of least resistance 16 feet.

The tamping (as already stated) 25 feet.

It was known to the Director, and Captain Williams, by the general plan, that the nearest countermine was 35 feet distant from the centre of the charge, but the assailants believed themselves to be much closer.

Effect of the Mine No. II.

The mine was exploded at 3 o'clock P.M., and produced a crater measuring about 24 feet in diameter, and 4 feet 6 inches in depth at the centre, but it was so shallow at the lip as to afford very little cover. It was, however, crowned instantly after the explosion by two brigades of Sappers previously appointed to

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of a man passing through it, for the purpose of digging out and loading a chamber at the end of it; whereas Lieutenant Penrice keeps the bore as small as possible, in order to form, with less after-labour, the chamber of his principal charge. The latter process is suited to every soil, but the former would be attended with risk in any but tenacious soil.

[6] Half-bushel sand-bags would probably be found convenient for tamping, and are worth a trial.

Defence.

25th Oct. 5th day.

when, owing to the unfavourable state of the weather, the men were allowed to return to their barracks.

26th Oct. 6th day.

The boring commenced on the 24th in gallery *C* 2 was continued. At 11 o'clock A.M. the miners reported to Lieut. Penrice that the boring bit appeared to be in contact with some wooden substance. An exceedingly small gallery, without casing, and somewhat in the form of a barrel drain, was driven in the direction of the bore, to ascertain whether the obstruction was part of the side sheeting of the besiegers' gallery, or the powder box containing a charge. The besiegers' miners were distinctly heard.

See Plate C, marked *a′—b′—*

Owing to the unfavourable nature of the soil, and to the want of proper supports, the earth fell in on the besieged miners, when they had actually reached within 3 feet of the assailants' work; and every subsequent endeavour to advance was ineffectual. At length, abandoning that attempt, an effort was made to flood the assailants' charge, by forcing water into the chamber by means of a fire-engine; but before this could be accomplished, the whole of the workmen on both sides retired, in compliance with the orders of the Director, in consequence of the besiegers having given notice that they were ready to fire a mine.

Attack.

25th Oct. 5th day.

that duty. The lodgement was speedily completed, and was a very respectable one. A descending ramp was immediately commenced, towards the most advanced part of the crater, for the purpose of driving forward a fresh gallery (*z*), which was pushed in advance 12 feet.

When this mine was fired, the superincumbent earth was very gently raised up, and fell down almost in the same place, none of it being scattered to a distance.

The centre gallery (*x*) was advanced beyond the chamber, to the distance of 5 feet, and another small branch made to the left, with a fresh chamber to the right.

26th Oct. 6th day. Mine No. III.

The centre gallery (*x*) was prepared this morning for a charge. At nine o'clock the loading was commenced with a charge of 300 ℔s. The object which Captain Wynne had in forming this mine was to extend the lodgement made on the previous day, to destroy any countermines which might fall within its influence, and to facilitate a subsequent advance.

A chamber was formed in a small return at the head of gallery *x*, which had by this time attained a total length of 53 feet.

The battery in front of the third parallel, being now supposed to have fulfilled its object, was dismantled, and the guns were withdrawn.

The tamping of the mine was about 21 feet, and was finished in 3½ hours.[7]

At half-past two o'clock the signal was given by the assailants that all was ready, and at three o'clock, the ground being cleared of spectators, and the miners removed from the whole of the galleries, the mine was fired.

This mine was fired with powder hose.

Character of Mine No. III.

The charge was 300 ℔s.

Line from the charge to the surface 20 feet.

Ditto to the head of the nearest countermine gallery (*C* 2) 9 feet.

Length of tamping 21 feet.

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[7] This branch could not have been efficiently tamped, from 2 to 3 feet an hour being the full extent of tamping that can be performed, when the earth is well rammed.

DEFENCE.
26th Oct.
6th day.

After the explosion, the state of the countermine gallery *C* 2 was examined.

Five frames adjoining the head of the gallery were found to be crippled, but not thrown down, although their distance from the centre of the charge could not have exceeded 10 feet. This was the only injury which the countermine gallery had sustained.[8]

During the morning a charge had been placed, containing 54 lbs. of gunpowder, in gallery *C* 1, with the view of blowing up a lodgement which the besiegers had established nearly over it.

The Director, having examined the works after the besiegers' explosion, and their subsequent discovery of one of the countermine galleries, determined that the besiegers should be placed in possession of the gallery and branches of the countermines in advance of the point of contact.

Two hours' time were granted by the Director, during which the besieged were allowed to take steps to prevent the besiegers from advancing along the gallery *C*.

ATTACK.
26th Oct.
6th day.
Effect of the Mine No. III.

Very little alteration was apparent on the surface, the earth being very gently heaved up, and falling down nearly in the same place, (as in Mine No. II.) The form of the crater was therefore hardly distinguishable, but it appeared to be elliptical, measuring about 15 feet by 16 feet. Immediately over the charge the ground was broken so as to form a little cover, about 4 feet in depth. The gallery was so filled with smoke as to render it impossible for the miners to enter it for several hours, which confirms the opinion that the gallery was not efficiently tamped. The chamber was under the left embrasure of the battery.

Captain Wynne's object in firing a charge in a situation where it was calculated to injure his own work, was to destroy the gallery of the enemy, at which he was distinctly heard working. Every exertion was therefore made to gain time, and this led to the imperfect tamping. It was, however, performed with sandbags, which Captain Wynne reports to have been well rammed. The mining frames had been removed, and at the return, planks were placed against the bags, and were strutted to the opposite side of the branch.

Immediately after the explosion, the crater was crowned and connected with the sap proceeding from the former crater on its left. Distance of Flying Sap 55 feet. From the end of this sap, which was the most advanced point, the besiegers commenced sinking a shaft, intended to be of the depth of 7 or 8 feet, from the bottom of which it was proposed to push on a fresh gallery; but on arriving at the depth of 3 feet below the bottom of the trench of the lodgement, the miners came upon a gallery (*C*) of the garrison, and therefore all further proceedings were suspended, according to orders previously issued by the Director, to avoid personal conflict between the opposing parties.

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[8] From the above-stated result, it is to be inferred that moderately charged mines may be fired, very near to the heads of galleries, without injuring them materially; and it would therefore seem to be essential, where it is desired to destroy an opposing gallery, to lodge the charge in such a position, that its action shall be against the side, roof, or sole of such work.

DEFENCE.

ATTACK.

26th Oct. 6th day.

Right gallery (*w*) advanced 5 feet.

Left gallery (*z*) advanced 2 feet. Total length 14 feet. Soil loose and difficult to sustain.

On the 27th and 28th October, the officers, non-commissioned officers, and men, were employed on military duties.

29th Oct. 7th day.

Mine No. IV.

Shortly after eight o'clock A. M., the garrison having sounded the warning bugle, a mine was fired from gallery *C* 2, for the purpose of rendering that gallery, and the advanced part of gallery *C*, useless to the assailants.

Lieut. Penrice was permitted to take this step, as, on actual service, such a charge would have been previously prepared for the purpose.[9]

Character of Mine No. IV.

The charge was 25 ℔s.

The line to the surface of the glacis was 13 feet.

The tamping was 8 feet.

The least resistance was in a line towards Captain Wynne's shaft and the broken ground around it, and as the earth in that direction possessed but little tenacity, pieces of plank and clods of earth were thrown to a considerable height by the explosion.

Effect of the Mine No. IV.

The effect was very injurious to the surrounding portion of the countermines. The shaft which had been formed at the junction of the five branches and galleries[10] shown on the plan, collapsed and fell in, and thus cut off the communication into galleries *C* 1 and *C* 2, which had by the decision of the Director been assigned to the assailants. However, it would have been open to Lieut. Penrice to have fired the charge of 54 ℔s. of powder, which, as before stated, had been lodged by him on the

29th Oct. 7th day.

Operations commenced this morning at 6 o'clock, but very little work was done this day.

Gallery *w* was driven forward 3 feet during the day.

The lodgement was extended 10 gabions towards the right by sap. The right gallery was pushed on 3 feet, (total length 53 feet,) and a proportion of the countermine gallery, surrendered by order of the Director, was cleared of the tamping placed in it by Lieut. Penrice during the two hours allowed to him.

At about 8 o'clock A. M. the warning bugle was sounded by the besieged, as a notice that they were prepared to fire a mine, and both parties were in consequence ordered to retire. This mine was fired prematurely, and before the positive sanction of the Director had been obtained, which led to his issuing an order prohibiting any future mine being fired, excepting his personal or written directions should have been received by the Officer in charge.[11]

After the explosion, the crater was crowned by two brigades of Sappers, by the Flying Sap. The original lodgement remained uninjured, and from the cracked and broken state of the ground for about 6 yards in front, the assailants were enabled to push their works that far in advance.

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[9] The besieged would, on actual service, have had strong barricade gates, which would have been immediately closed, and backed up with sand-bags. The gallery would also have been tamped backwards, having occasional small charges of gunpowder lodged in the tamping, for the purpose of wounding the besiegers' miners in any attempt they might make to penetrate along this gallery by untamping.

[10] Galleries *C*, *C* 1, *C* 2, *C* 3, and *C* 4.

[11] Orders were at the same time promulgated, that no powder should be issued from the laboratory, excepting by the written order of the Director, on the application of the Officer in charge.

DEFENCE.

29th Oct.
7th day.

ATTACK.

29th Oct.
7th day.

26th at the end of gallery *C* 1, but he had omitted the precaution, before firing mine No. IV. in gallery *C* 2, to lead the hose sufficiently far towards the counterscarp to insure his having access to it: the consequence was, that the charge of 54 lbs. was obliged to be abandoned to the assailants.

Gallery *C* 4 was by the concussion almost filled with earth, and rendered impassable for the distance of nearly 15 feet from its head. It should be remarked, that in this part of the gallery the sheeting was imperfect.

In proceeding along the gallery *C*, about half an hour after the explosion, the accumulation of smoke in the troughs or hollows formed by the gradients of the gallery was very remarkable, whilst the upper part of the planes was nearly free from it.

See Plate C, marked VII^1. and VII^2.

The advance of the besiegers' double sap having been observed, a chamber was formed at the end of gallery B, with the view of destroying the trench. Ten feet in rear of the chamber, and at right angles to the left, a small branch was driven: the object was to place another charge at its extremity, and by firing both together, to increase the surface of explosion. This branch was made to ascend 1 foot in 3.

In order to guard the gallery B from the effect of these mines, it was strengthened by shoring.

During the afternoon, Lieut. Penrice effected an entrance into gallery *C* (which had been isolated by the morning's explosion of mine No. IV.), and discovered his hose. He attached considerable importance to the firing of the mine with which this hose was connected, as he hoped it would destroy part of the besiegers' lodgement.

The Officer charged with the firing inadvertently took a lighted portfire along the galleries, and being unable to find the hose immediately on his arrival at the point for ignition, the gallery became so filled with smoke, and so offensive from the smell of the burning portfire, as to oblige him to retire. Some time

DEFENCE.

29th Oct. 7th day.

elapsed (probably half an hour) before the gallery could be re-entered and the train lighted. The train had been formed of short lengths of Bickford's fuse, tied together; and from this defective arrangement the fire was not carried on to the chamber, and no explosion took place.

Mine No. V.

With the view to harass the assailants, and drive them from the centre gallery *C*, which had been given over by the Director, the besieged lodged a charge of 5 ℔s. of powder close to the point surrendered, and commenced tamping the gallery.

30th Oct. 8th day.

Mine No. V.

At 8 o'clock A. M. the small fougasse of 5 ℔s. was, after due warning, and the withdrawal of the men, fired by Lieut. Penrice. Taking advantage of the delay this would occasion, Lieut. Penrice placed a charge of 25 ℔s. in a chamber on the left side of the gallery *C*, and 12 feet in rear of the chamber of the fougasse of 5 ℔s.

Mine No. VI.

The object of the larger charge (No. VI.) of 25 ℔s. was to injure a portion of the gallery, and to render it unserviceable to the besiegers. After the signal for firing being given, and the men withdrawn, the explosion took place at $\frac{1}{4}$ before 12 o'clock A. M.

Character of Mine No. VI.

The charge was 25 ℔s.

The distance to the surface of the glacis 16 feet.

The line of least resistance was in the direction of the countermine gallery *C*, of which 8 feet was tamped.

Effect of the Mine No. VI.

There was no exterior movement of ground whatever, but the countermine gallery *C* was destroyed for a distance of 8 feet from the tamping, and frames were displaced to the extent of 25 feet from the charge.

The adjoining gallery (*C* 3) was likewise filled in to the distance of 30 feet.

Immediately after the explosion, the Director, accompanied by Captain Williams and Lieut. Clarke, advanced as near to the tamping as the insecure state of the frames would permit, and they found, that although there was smoke in the gallery, there was no difficulty of respiration, and the candles burned brightly. After re-

ATTACK.

29th Oct. 7th day.

30th Oct. 8th day.

Galleries *w* and *z* were this day respectively advanced 6 feet and 7 feet. The double sap was also pushed forward 10 feet, and the sappers were then withdrawn, in order to wait for the further progress of the gallery *w*. The lodgement was extended towards the double sap by the single sap, and additional communications established with the third parallel.

This explosion produced no effect whatever on the under-ground works of the attack.

DEFENCE.

30th Oct. 8th day.

maining there for some time they retired, the miners having proceeded to their dinners.

Mine No. VII.[1]

At an earlier period of the day, a charge of 100 ℔s. (No. VII.[1]) was lodged in the chamber at the extremity of gallery B, and a branch driven to the left, 9 feet in the rear, to obtain soil for tamping. At about 2 o'clock P.M. (that is, about 2¼ hours after the explosion,) an accident occurred which caused the deepest regret to every one engaged in these operations. At about 2 hours after the explosion of the 25 ℔s. of powder, a brigade of miners commenced work in gallery *C*, under the orders of Lieut. Moggridge, in putting up the frames that had been knocked down. This officer, observing the lights to burn dimly, and feeling a deficiency of air, ordered his party to withdraw, and he himself retired towards the mouth of the gallery, to examine the ventilating pipes. Whilst so occupied, he heard an alarm that an accident had happened at the head of the gallery, and repairing instantly to the spot, he found two of his miners senseless. A very gallant attempt was made by Lieut. Moggridge to drag out the foremost man, but, overcome by the foul air, he himself fainted, and was carried out by Colour-Serjeant G. Shepherd and Private J. Murphy, R. S. and M. After some difficulty and delay, which may be attributed chiefly to the undulating form of the gallery, the two men were rescued, but not until a third had fainted. Medical aid was fortunately at hand, and two out of the three miners were restored, but unhappily the third (Private James Sullivan, of the East India Company's Sappers and Miners) was brought out dead, and all attempts for his recovery proved unsuccessful. From the results of a subsequent investigation before a Court of Inquiry, it appeared that the two men, instead of promptly obeying the command to retire, had loitered in the gallery, and that one of them afterwards either removed a plank, or otherwise disturbed the earth with his pick, when it is supposed that a sudden inbreak of carbonic acid gas immediately prostrated the men. Yet it would appear, from

ATTACK.

30th Oct. 8th day.

DEFENCE.

30th Oct.
8th day.

the evidence produced before the Court of Inquiry, that lights were burning on or near the ground the whole time; and it is certain, that instantly after the last man was carried out of the gallery, it was traversed in its whole length by Lance-Corporal J. Wood, of the Royal Sappers and Miners, who carried a light in his hand, and experienced no great difficulty in breathing.

ATTACK.

30th Oct.
8th day.

On the 31st of October, the officers, non-commissioned officers, and men, were employed on military duties.

1st Nov.
9th day.

The Director went through the whole of the countermines this morning before any of the working parties were allowed to enter. Having thus satisfied himself of their freedom from choke damp, he approved of the following plan of defence, submitted to him, in the absence of Lieut. Penrice, R. E.,[12] by the under-mentioned Officers of Royal Engineers, viz.:

Lieut. C. S. Hutchinson,
„ H. Wray,
„ J. Stokes,

to each of whom some special duty was assigned in the operations that follow.

At the end of gallery A, a charge of 50 ℔s. of powder was to be placed to the left, and well tamped.

In gallery *C* 3, a charge was also to be lodged, 51 feet from its junction with gallery A. Charge 25 ℔s. (No. VIII.)

Further; in gallery *C*, at a distance of 86 feet from the mouth, or 2 feet beyond the summit of the second gradient, a small branch was ordered to be excavated 10 feet, and rising 4 feet, to receive a charge, XIV.

By this disposition the besieged were enabled to meet their assailants on the extended front they had begun to show.

The quantity of powder disposable for the

1st Nov.
9th day.

The double sap on the right was pushed forward 12 gabions.

Galleries *w* and *z* advanced as follows:

Gallery *w* . . . 7 feet.
Do. *z* . . . 8 feet.

At two o'clock P. M., from the most advanced lodgement, the besieged pushed forward a single sap to the right, to join the double sap, so as to form a continuous communication from one extremity of the attack to the other; viz., from the gallery *z* on the left to the double sap on the right.

The besiegers now anticipated an explosion on their left, as the enemy were heard at work, and, as they conceived, in tamping rather below them, and about 12 feet distant. This was, however, an error.

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[12] Lieutenant Penrice was attacked with inflammatory sore throat, and cold, caught by over-exertion and exposure to the night air, for several successive nights, and was obliged to lay up for a couple of days, at the end of which he was summoned to Norfolk, to attend his father's death-bed; and from this period took no further part in the operations.

DEFENCE.

1st Nov.
9th day.

ATTACK.

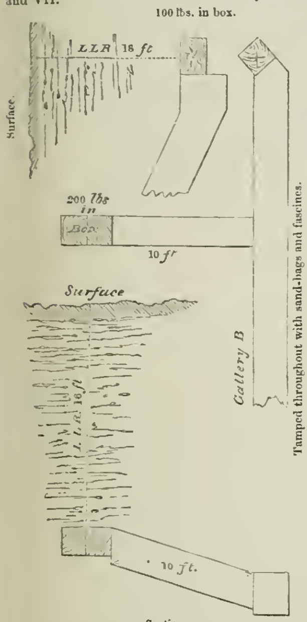
1st Nov.
9th day.

defence having been much diminished, the Director ordered the branches for the new mines to be inclined upwards as much as possible, with a view to diminish the line of least resistance.

The galleries were visited this day by the Secretary-at-War,[13] who appeared to take much interest in the siege operations.

Mines
Nos. VII.[1]
and VII.[2]

It has been stated, that a charge of 100 ℔s. (No. VII.[1]) was placed on a previous day at the extremity of gallery B, and this morning an additional charge of 200 ℔s. was placed in the branch already alluded to, with the object of injuring the double sap and the adjoining lodgement.



Sections.

At 5 o'clock P.M. these mines (Nos. VII.[1 and 2]) were ready for explosion, and the warning bugle was sounded for firing, on which the miners on both sides were withdrawn from the works. The tamping having been hastily carried on, for the purpose of getting it ready to admit of the explosion being witnessed by the Secretary-at-War, more than the usual number of men had been employed in the gallery, and the air had in consequence become so bad, as hardly to support the flame of a candle. Owing to this circumstance, it was found impracticable to light the portfire; the Director therefore ordered 26 feet of hose to be added, when ignition was effected without difficulty.

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[13] The Right Honourable Sir Thomas Freemantle, Bart.

DEFENCE.

1st Nov. 9th day.

Charges of the Mines Nos. VII.^{1} and VII.^{2}

The charges were 100 lbs. and 200 lbs.

The tamping, from 8 to 10 feet, being completed by fascines picketed down.[14]

Lines of least resistance about 14 feet and 16 feet respectively.

Effect of the Mines No. VII.

The explosion destroyed 24 feet of countermine gallery B, which arose chiefly from the insufficiency of the tamping.

Mine No. VIII.

A small mine (No. VIII.) was also fired in gallery *C* 3, with the view to prevent its advanced portions being serviceable to the assailants.

Character of Mine No. VIII.

The charge was 25 lbs.

The line of least resistance, measuring to the surface, 14 feet.

The tamping, 8 feet beyond the charge, and 5 feet behind it, using the soil of a branch excavated still further to the rear.

Effect of the Mine No. VIII.

A portion of the gallery A, nearest to the charge, although 24 feet distant, was injured, and rendered impassable.

ATTACK.

1st Nov. 9th day.

The head of the double sap was destroyed by the explosion of the enemy's mines, Nos. VII.$^{1 \text{ and } 2}$, together with a portion of the approach, for a length of 8 gabions. The sap rollers were also thrown over, thereby opening the trench to the fire from the parapets of the garrison.

The besiegers crowned the crater. This was, however, shallow, and afforded but very indifferent cover; so much so as to make it doubtful whether, in actual warfare, a crowning of it would have been practicable.

On the 2nd of November, the officers, non-commissioned officers, and men, were employed on military duties.

3rd Nov.

Sunday.

4th Nov. 10th day.

In consequence of the shattered state of the frames, caused by the explosion of mine No. VIII., it was found necessary to abandon the charge of 50 lbs., which had been placed at the head of gallery A, it being unsafe for the miners to pass to the charge.

After the explosion of mines Nos. VII.$^{1 \text{ and } 2}$ and VIII., it became necessary to take up a more retired line of defence, and the Committee of Officers before-named[15] made a proposition to the Director, to concentrate the operations towards the centre. The state of the extreme galleries A and B, combined with the deficiency of powder, induced these Officers to abandon all further attempt at the defence of those gal-

3rd Nov.

Sunday.

4th Nov. 10th day.

At 6 o'clock A.M. a large working party was employed in perfecting and extending the lodgement, 98 feet to the left, and a formidable front was presented to the fortress. This was done by Flying Sap, and good cover was obtained before daylight. The trench was nearly parallel to the crest of the glacis, and about 90 feet distant from it.

At 9 o'clock A.M. three half-brigades, each consisting of 1 officer, 1 non-commissioned officer, and 4 privates, commenced sinking three shafts in the lodgement, one on the extreme left, and the two others with intervals of 36 and 26 feet respectively between them. The ground was favourable, and after 7 hours' work, each

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[14] In order to obtain the materials for tamping the mines Nos. VII.^{1} and ^{2}, branches were driven right and left of the main gallery, and the earth was wheeled forward as required. This arrangement was found very convenient, and admitted of great expedition.

[15] Lieutenants Hutchinson, Wray, and Stokes, R.E.—Vide description, in this Journal, of Defence of 1st November.

DEFENCE.
4th Nov.
10th day.

leries; the more especially as the besiegers had established themselves so far in advance in the direction of the centre; and it was determined to make efforts to drive them from the advanced lodgements by ordinary and undercharged mines, which, while destroying the lodgement, and exposing the guard of the trenches and workmen to the fire from the parapet of the place, would produce only craters of moderate dimensions.

Mines Nos. IX. and XIII.

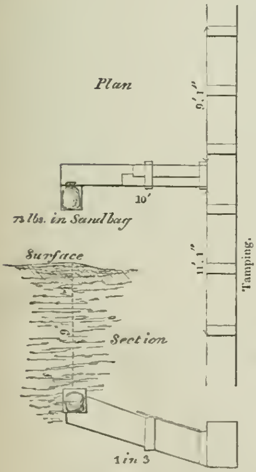
Section on line A B, Plate C.

To carry out this plan, Lieut. Stokes was directed to prepare in gallery $C4$, two mines, one of 130 ℔s., and the other of 100 ℔s.: the former to be placed at the extreme end of a small branch, 12 feet in length, to the right of the gallery, and 40 feet 6 inches from its junction with gallery B: the latter, also at the end of a small branch, but on the opposite side of the gallery, and 35 feet distant from the junction with gallery B. About 4 feet of one, and 2 feet of the other branch, were driven this day.

PARTY EMPLOYED.

Lieut. Stokes, R. E.
1 non-commissioned officer.
5 privates.

Mine No. XIV.



In the centre gallery (C), Lieut. Clarke, R.E., was directed to prolong the branch, commenced on the 1st instant, to 10 feet, and to lodge in a chamber at its extremity a charge of 73 ℔s. This gallery was formed with an ascent of 1 foot in 3, to diminish the line of least resistance to 10 feet. The excavated earth was applied to tamp 7 feet 6 inches of gallery C, just beyond the branch, so as to re-

ATTACK.
4th Nov.
10th day.

party had completed a shaft 10 feet deep,[16] and 4 feet in diameter, and placed the first frame of the galleries proposed to be driven towards the work.

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[16] That is, below the sole of the trench, and therefore 13 feet beneath the surface of the glacis.

DEFENCE.

4th Nov. 10th day.

sist the action of the gunpowder in that direction.

The branch from gallery *C* 3, made by Lieut. Kerr, R. E., on the 1st instant, at 41 feet from the junction, was so injured by the explosion of mine No. VIII., that the Director ordered it to be abandoned, and another branch commenced 15 feet further to the rear, which subsequently became mine No. XV. This branch was driven 10 feet, rising at a slope of 1 in 3, to diminish the line of least resistance, and it then turned off at an angle of 45°, to remove the charge further from the abandoned branch beyond it.

During the time Lieut. Stokes's party were at work, the miners were distinctly heard in the galleries of the assailants, but it was difficult from the sound to determine their position. This, however, could be fixed within certain limits; for instance, at the point where Lieut. Stokes commenced his branch, the sound was evidently further up the gallery; whereas, on advancing 20 paces, it was equally clear that the point had been passed where the assailants were at work.

5th Nov. 11th day.

The miners continued working at their several branches, &c.

Gallery *C* 4.—The party commenced at 4 o'clock A.M., and after 3 hours' work had completed 6 feet of gallery, and a chamber 2 feet square to its left. The left branch was in the same time pushed on 4 feet 6 inches.

It being considered that the chamber of the right branch was not far enough advanced, it was enlarged to the size of the branch, viz., 3 feet 6 inches by 2 feet 6 inches, and carried on 4 feet more, when another chamber was made, 2 feet square; the whole ascending at an angle of 45°, and the chamber being placed on a level with the top of the gallery. The work was finished in 7 hours. The charge of 130 lbs. was placed in two sand-bags, to one of which was attached 32 feet of half-inch powder hose, and to the other, 30 feet of Bickford's fuse, as a precaution against failure. The hose was laid in its casing, and in 5 hours' work 10 feet of

ATTACK.

4th Nov. 10th day.

5th Nov. 11th day.

Plan and section on gallery *t*. See Plate C. Mine No. XI.

Ensigns Fraser and Winscom were placed in charge of the left gallery (*t*), each having a party of 1 non-commissioned officer and 4 privates under their orders, and they were directed to relieve each other every 4 hours. This gallery was driven 10 feet further. At that distance, a drift was pushed 2 feet forward, on a level half-way between the capsill and groundsill of the gallery. A chamber to the right was formed at its extremity, to contain 150 lbs. of powder. The whole was finished in 6 hours, and the charge was then lodged and tamped.

Plate C.

Centre gallery (*s*) was placed under the charge of Ensigns Glover and Young, having each a party of 1 non-commissioned officer and 4 privates, to be relieved as in the left gallery. When this gallery had advanced 6 feet, a large cavity was discovered to the left, which appeared to have been caused by the falling in of one of the countermine galleries, and the ground

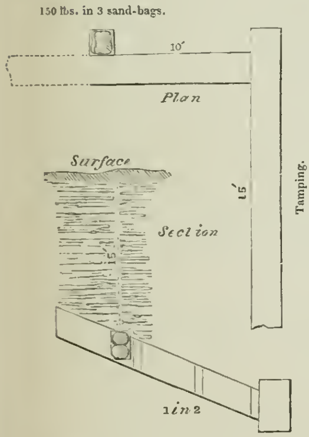
Defence. 5th Nov. 11th day. the branch was strongly tamped with sand-bags and rammed earth. Great difficulty arose in the tamping from the steepness of the ascent.

The branch to the left was stopped, to avoid interfering with the right branch; but a dépôt of sand-bags had been prepared beforehand by Lieut. Stokes's foresight.

Centre gallery *C*.—The branch and chamber were completed in 4½ hours' work, and the mine (marked in plan No. XIV.) was loaded, the powder being contained in a tarred sand-bag, to which was added an inch powder hose (filled) laid in casing tube. The tamping, which was commenced with sand-bags, was 10 feet long in the branch, and 11 feet 6 inches in the gallery.

Left branch of gallery *C* 3.—The miners under Lieuts. Kerr and Roe commenced work at 6 o'clock A.M. The excavated earth was used to tamp up the main gallery beyond the branch. Having driven about 16 feet of the branch, it was intended to make a return to the left, for the chamber, at the distance of 4 feet, in which 100 lbs. of powder was to be lodged; but the ground proved so unsafe, that it was necessary to abandon that intention, and to form a chamber on the right of the branch, at only 10 feet distance from the gallery *C* 3. As this increased the line of least resistance, the charge was augmented to 150 lbs., placed in three bags, with about 20 feet of half-inch powder hose, laid in a casing tube, and attached to the centre bag. The branch was well tamped, by earth excavated from the opposite side of the gallery, at a point 15 feet nearer to the junction with gallery A.

Mine No. XV.



Attack. 5th Nov. 11th day. was found so insecure, that it became necessary to abandon any further prosecution of the work. A Flying Sap was therefore pushed out, to cover an advanced shaft (*o*), which was substituted for the abandoned one, and by working throughout the night, sufficient progress was made to admit of its being loaded on the following morning. Mine No. XII.

The right gallery (*r*) was under the direction of Ensigns Dyas and Paton, of the Honourable East India Company's Engineers, with similar parties of miners. It was pushed forward 4 feet directly to the front, and then inclined 45° to the right, for a distance of 7 feet further, when a chamber was made to the left, 2 feet above the sole of the gallery, to diminish the line of least resistance to 11 feet 6 inches. This work was done in 6½ hours, and the loading with 200 lbs. of powder was completed in three quarters of an hour. Mine No. X.

The Sappers were employed in perfecting the trenches, and forming sand-bag loopholes on the parapets of the lodgements.

DEFENCE. 6th Nov. 12th day.

In gallery *C* 4, a charge of 100 lbs. was placed in the left branch for mine No. XIII., and the whole branch was tamped up for a distance of 10 feet, in 7 hours: besides which, a strong barricade was thrown across the gallery at its junction with the branch. From thence the tamping extended 6 feet 6 inches along the gallery, and this mass was common in its resistance to the mine No. IX. as well as to the mine No. XIII., so that the total extent of tamping for the former was 30 feet, and for the latter 16 feet.

The mines in galleries *C* and *C* 3 were completed by 11 o'clock A.M.

ATTACK. 6th Nov. 12th day.

The party under Ensign Young's command commenced work shortly after midnight, and having sunk the shaft (*o*) to the required depth, pushed forward a branch for a few feet, dug their chamber so as to have a line of least resistance of 12 feet, and tamped to the surface of the shaft. The tamping was completed in $2\frac{3}{4}$ hours, by employing 4 men to throw in the earth, and 3 to ram it.

Gallery *r*, 11 feet long, and the shaft 10 feet deep, were tamped in $5\frac{1}{4}$ hours.

The gallery *t*, of the same dimensions, was tamped in $4\frac{3}{4}$ hours. Both these galleries had parties of the same strength as the shaft *o*.

ATTACK and DEFENCE. 6th Nov. 12th day.

The Director being of opinion that the operations had been carried to a sufficient extent for the present season, determined that they should close on this day, by the firing of the whole of the mines that were charged, and combining the explosions with the advance of the upper ground-works, supported by infantry, carrying on the various movements as nearly as possible in the manner they would be conducted on actual service; and the Commandant of the Garrison, Colonel Sir Thomas Willshire, Bart., K.C.B., directed that the 11th Regiment, under the command of Lieut.-Colonel Sir Michael Creagh, K.H., should be employed in the trenches on this occasion; two companies, however, being reserved to represent the garrison. These companies were posted on the ravelin, and the Duke of Cumberland's bastion.

The following general orders were given by Lieut.-Colonel Sir Frederic Smith, K.H., the Director, and communicated to all the parties concerned:

"Captain Whitmore, R.E., will direct the operations for the defensive, and Captain Wynne, R.E., those for the offensive mines, under such instructions as he may receive from Captain Williams, R.E., with reference to the movements of the attacking troops, who will be conducted to their several posts by the latter officer.

"Lieut.-Colonel Sir Michael Creagh, K.H., of the 11th Regiment, is requested to remain with the Director, in order that combined arrangements may be made for the movements of both forces.

"At ½ past 1 o'clock, one detachment of the 11th Regiment will man the left face of the ravelin, and the right face of the Duke of Cumberland's bastion.

"Another portion of that regiment will occupy the first parallel, push forward one company to occupy the second parallel, another the third parallel, and a fourth to man the lodgement and the right side of the double sap.

"Ensign Drummond, of the E. I. C. Engineers, will be attached to the troops on the Duke of Cumberland's bastion; Ensign Hyde, E. I. C. Engineers, to the troops in the ravelin; Ensign Harris, E. I. C. Engineers, with those in the lodgement and double sap; Ensign Glover in the third parallel; and Ensign Hutchinson in the second parallel.

"The Officers of Engineers and Sappers and Miners of the attack will (with the exception of Ensigns Fraser, Paton, and Fife) assemble with the troops in the first parallel, and will move forward to the lodgement, under Captain Wynne's orders, on the 'advance' being sounded.

ATTACK and DEFENCE.

6th Nov. 12th day.

"Ensigns Fraser, Paton, and Fife, of the E. I. C. Engineers, will take post at their respective charges, which they will on no account quit, until ordered, as underneath.

"The Officers of Engineers and the Sappers and Miners of the defence will take post in the ravelin, under Captain Whitmore, R.E., the gates of the countermines being locked.

"Lieutenants Stokes, Clarke, and Kerr, of the Royal Engineers, will respectively provide themselves with safety lamps, a knife, a piece of string, and a piece of portfire and slowmatch.

"The first mining operation will be defensive. On the signal being sounded by the bugler of the 11th Regiment for firing, the men of that regiment will commence musketry file firing through loopholes. The 11th bugler will then sound 'cease firing.' The Sapper bugler with Sir Frederic Smith will sound the regimental private call, and afterwards the 'lie down.' After this signal the 11th bugler will sound the retreat, and the whole of the attacking force, including Ensigns Fraser, Paton, and Fife, of the E. I. C. Engineers, will take post in the first parallel. Lieut. Stokes, R.E., will then proceed at once, attended by Lance-Corporal R. Bake, of the E. I. C. Sappers and Miners, and will fire, by slowmatch, a portfire now attached to the powder hose, as well as the Bickford's fuse. He will instantly retire to the ravelin, and report through Captain Whitmore, R.E., to Sir Frederic Smith, that he has performed this duty.

"On the explosion taking place, the advance will be sounded, and Captain Wynne will push forward with the *three* firing Officers, each provided with slowmatch, knife, and portfire, preceded by the light company of the 11th Regiment, who will take post as in the first instance. The musketry fire will be resumed on both sides by sound of the bugle, excepting in the advanced lodgement; and Captain Wynne, R. E., will with his Sappers, and Ensigns Dyas, O'Connell, Young, and Winscom, of the E. I. C. Engineers, crown any entonnoir which may have been made by Lieut. Stokes's mine. The firing Officers will take post at their respective charges, which they will take care to protect from the fire of the infantry. The 'cease firing,' and 'retreat,' will then be sounded, and the whole of the attacking force will retire again to the first parallel, excepting Captain Wynne and the firing officers (Ensigns Fraser, Paton, and Fife), and a non-commissioned officer of Sappers attached to each. The 11th Regiment will also retire from the ravelin, and take post upon the Duke of Cumberland's bastion. The Royal Sappers and Miners' private call will then be sounded, with the 'lie down,' and if Captain Williams should perceive that there is no risk of danger to any of the troops or spectators, he will instruct Captain Wynne to have his mines fired: 4 inches of portfire will have been attached to the hoses of the three mines. Immediately after the explosion, the 'advance' will be sounded, and the Engineer force, as well as that of the 11th Regiment, will resume their old positions, both in the attack and defence. Captain Wynne will then crown his entonnoir by Flying Sap, covered as much as possible by the fire of the infantry.

"When the lodgement shall have been completed, the 'cease firing' will be sounded, and the 'retreat' ordered for the whole of the attacking force, who will resume their position in the first parallel. The Sappers' private call, and 'lie down,' will be sounded, on which Lieut. Hutchinson, R.E., will fire his charge (mine No. XIII.) by the voltaic battery. Unless ordered to advance and crown Lieut. Hutchinson's entonnoir, the forces will remain as before. The Sappers' private call will again be sounded, and the 'lie down,' on which Lieuts. Clarke and Kerr will advance, receiving their orders from Lieut. Wray, R. E., who will be responsible to provide them with all the necessary implements, apparatus, and stores, for this purpose. The slowmatch is to be used in each case, unless it should fail, when recourse will be had to the portfire. Each piece of portfire inserted in the hose in these mines will be 3 inches long. Lieut. Wray will accompany Lieuts. Clarke and Kerr to the mouth of the mines, and if one portfire should ignite and the

ATTACK and DEFENCE.

6th Nov. 12th day.

other not, Lieut. Wray will be responsible to require both Officers to retire from the gallery. He will follow them out of the gallery, and report to the Director, through Captain Whitmore, that he has performed this duty.

"The 'advance' will then be sounded, and Captain Wynne will come forward with his Officers and Sappers to crown the entonnoir, protected by the infantry fire of the 11th Regiment in the trenches. The force on the ravelin, and Duke of Cumberland's bastion, will open a musketry fire on the besiegers."

The movements of the troops, and the mining operations on both sides, were conducted according to the foregoing arrangements, and the results were precisely what was desired in every instance.

Mine No. IX. Character and effect.

Charge No. IX. was 130 ℔s.

The line of least resistance 11 ft. 6 in.

The tamping was 16 feet.

This mine was fired by Lieut. Stokes, who lighted not only a portfire attached to the powder hose, but also the Bickford's fuse. The former missed, and the charge was fired by the latter.

14 feet of the lodgement was thrown over. The Sappers rushed forward, and crowned the crater, which measured about 20 feet by 18 feet, but only 3 ft. 6 in. in depth; and re-established the work. They were followed by the guards of the trenches, between whom and the garrison a heavy fire was maintained. This having ceased, the assailants next sprung the three following mines.

Mines No. X. Charge 200 ℔s. Line of least resistance 11 feet 6 inches.

No. XI. Charge 150 ℔s. Line of least resistance 12 feet 6 inches.

No. XII. Charge 150 ℔s. Line of least resistance 11 feet 6 inches.

The tamping may be considered as equal to the line of least resistance in each of the foregoing mines. The distance from the chamber of the mine No. X. to that of No. XII. was about 65 feet. The distance between mines Nos. XI. and XII. about 15 feet.

The effect from the mines being fired simultaneously was exceedingly imposing.

Mine No. X. formed a crater, 29 feet by 25 feet, by 6 feet deep.

Mines Nos. XI. and XII. produced respectively craters of 30′ × 24′, and 7 feet deep, and 22′ × 17′ × 3′ deep.

The series of craters formed most excellent cover. The whole were crowned, and a new lodgement established; a musketry fire being kept up the whole time from the ravelin and trenches.

Mines Nos. XIII. XIV. and XV.

No sooner had the besiegers effected this work, than the besieged prepared to destroy it. Mines Nos. XIII. XIV. and XV. were fired, and again overthrew the lodgement. The character, &c. of these mines has been already given.

Shortly after the last explosions, the lodgement was restored by the Sappers, under the protecting fire from the trenches, and with its re-establishment concluded the operations.

Remarks resulting from the Practice detailed in the foregoing Journal.

As the mining operations which had previously been carried on at this establishment were on a comparatively very limited scale, consisting chiefly of isolated experiments in firing single or conjunct charges of gunpowder, and of the manual labour required, to instruct the officers and men practically in sinking shafts, driving galleries and branches, and forming chambers, which were occasionally loaded and tamped; we found on entering upon the more extensive operations just detailed, that we had many wants in the 'materiel' which our stores either did not supply at all, or, at best, very imperfectly, and that we were very deficient in that description of the 'personnel' amongst our non-commissioned officers, which is almost indispensable for the safety of those employed.

With reference to Lieut. Penrice's system of countermines, almost all the officers employed here have arrived at the conclusion, that any arrangement of galleries in a series of ascending and descending planes is objectionable; for, although such a system may, in many instances, admit of the besieged reaching the enemy with more facility than by countermine galleries in a continuous plane, yet it is much more laborious in construction, impedes ventilation, renders the communication much less convenient, interferes with the lighting, and increases the labour in tamping all such charges as are placed in branches proceeding from the ascending planes. Greater general convenience would result from having all the direct main galleries in one plane, or nearly so, from end to end, with branches right and left, inclined downwards from the point of junction, for the purpose of more readily loading and tamping. If a system of countermines consist of direct galleries, pushed out perpendicularly, or nearly so, to the counterscarp, there seems to be no reason why these should be all on the same level; on the contrary, it would be preferable to construct them on different levels, in order to intercept the enemy both near to the surface and at a greater depth.

It further appeared, that a system of countermines having points of junction where several galleries meet is objectionable; for if the besiegers break into any one of such galleries, there is a risk of their getting possession of a great extent of the system.

It was observed that much convenience would result from forming, at every 25 feet, a recess of about 6 feet in length for the stowage of stores, and indeed each alternate recess could advantageously be made somewhat longer. It was obvious, whether a counterscarp gallery is used or not, that the end of every direct gallery should open into the ditch, for the purpose of improving the ventilation. All countermine galleries should also have ventilation through the roof, which may be effected by air-holes, ascending at as low an angle as can conveniently be managed, and directed towards the rear, to prevent their falling into the hands of the enemy. These ventilators may be kept open by using metal pipes. The ventilation is also improved very much by having the first part or root of the direct galleries of large dimensions. At this end of each direct gallery a large bellows or fan should invariably be placed, and well-jointed tubes of 3 inches in diameter should be connected therewith; it being borne in mind that the tubes should always extend to the point where men may be at work or posted. At the extreme end of each gallery a chamber should be formed, of 5 or 6 feet square, or of an octagonal shape, as a post or guard-room for the besieged miners to listen for the besiegers, or from whence they should drive branches to meet or intercept them.

Borings may be made from this chamber, by augers, to the distance of 15 feet, to form listening tubes for the purpose of ascertaining more readily the direction of any galleries at which the enemy may be working, and the borings could be used at the discretion of the engineer, to load small charges, according to Lieut. Penrice's system. It was found that when the opposing miners were working at the distance of above 10 or 12 feet from any gallery, it was next to impossible to determine the precise position or distance, and therefore these borings would be very useful.

It appeared that galleries exposed to the action of the enemy's powder were much more easily destroyed when not close cased. It will be desirable to try experiments for the purpose of ascertaining whether much benefit would result from strutting these galleries before being subject to such action. It also appeared that when the sides and tops of galleries were supported throughout, the mine frame introduced into the Service some years back, viz., the 'chasis à la Holandaise,' resists the influence of the enemy's powder better than the frames and sheeting which were in use in our Service at an earlier period.

It is proper to commence the ventilation, by bellows, when a gallery has attained the length of 50 feet, for although at that distance the lives of the miners are not exposed to any risk from foul air, yet the atmosphere so far from the mouth of the gallery is very impure. It is usual to fix the ventilating tubes along the side of the gallery near the roof, but it is better to place them near the sole of the gallery when it can be managed. It was found necessary to give peremptory orders to have as few lights as possible in a mine, to avoid consuming the pure air, and that they should be placed, when practicable, above the level of the heads of the men when kneeling at their work. One candle should be at the head of the gallery, and the next at least 50 feet in rear of it, when the gallery is straight and of that length; and if the gallery is not straight, a lamp or candle is required at every second angle or turn, and it should be so placed as to light both ways.

Orders were given to the Officer in charge of each mine, either to be at the head of the gallery himself, or to place an experienced man there, and on no account to allow a miner to cut away more earth than might be necessary to give space for setting the frames, nor to let any man work unless protected over head by frames or sheeting.

The direction of every gallery should be fixed with the compass, and the slope determined with the spirit level, at every fourth frame, by the Officer on duty, who should report that he has done so. The Officer must be held strictly responsible, never to have more men in a gallery than are indispensable for carrying on the work with vigour.

By the experience of the recent practice, the necessity has been clearly proved of tamping nearly 1½ times the line of least resistance. And it has also been observed, that the effect of the powder in the required direction is very much lessened by lodging the charge at the bottom of a shaft, or at the end of a gallery. The chamber should be formed in a branch driven at least 5 or 6 feet from the former, and in a return right or left of the latter.

It was found that the best and most rapid tamping is executed with clay, worked up into the form of large bricks, and half-dried. Tamping with sand-bags was the next quickest way, but this is very expensive, and the bushel bag is unwieldy. If sand-bags should be used at all, the half-bushel bag would be preferable to the bushel bag. Well rammed earth forms the best tamping, so far as solidity is concerned, and great additional resistance to the action of the charge along the gallery is produced by forming barricades across the branch in the following manner. At intervals of 5 feet, a wall of one course of sand-bags should be built from one side of the gallery or branch to the other; sheeting should then be placed in the rear of these bags across the gallery also, with the ends fixed in a chase cut out about 6 inches or a foot in depth, on each side of the gallery or branch. These planks are put in horizontally, or nearly so; and at the end of the tamping, another plank is placed vertically against them, supported by a strut, the butt end of which is bedded in the sole of the gallery.

It was deemed indispensable to lay down rigid rules for loading the mine, on which it is superfluous to remark that the greatest care is called for. The Officer in charge was desired to conduct the whole operation, and to rely on no one but himself in this important duty, which is made up of the following detail. To calculate the charge, and the size of the powder box; to determine the length of hose, the quantity of powder necessary to fill it, and the length of casing tube, as well as the number of return and priming boxes. He must also provide himself with portfire and slowmatch of good quality, and a safety lanthorn. It is of great moment that the hose should be perfectly filled, and this should be done under the eye of an Officer. If the mining operations are on a large scale, the powder magazine should be placed in charge of one Officer, and the laboratory, of another.

No powder should be issued except on the written order of the Director of the attack or defence. This order is a voucher for the Officer in charge of the magazine. It should specify the amount of every charge, when it will be wanted, to whom it is to be delivered, and whether it is to be placed in a box, or in a bag or bags. It should also specify the nature of the hose or fuse, and its length.

When ready for issuing, the Magazine Officer should mark on the box or bag the quantity it contains, and the name of the Officer to whom it should be delivered; and he should obtain from such Officer a receipt for what he may issue to him. The charge complete must be delivered over to an Officer or Non-commissioned Officer connected with the mine to be loaded, and ought to be carried, properly protected, to the gallery, by men belonging to the magazine.

The greatest attention is necessary to secure the end of the hose or fuse within the box or bag. If a box be used, the end of the hose should be passed through a hole on the top of the box, and a skewer passed through, to avoid its being drawn out accidentally. This end of the hose should be sewed up, to prevent its wasting powder.

As the success of the operation depends on the accurate performance of the various details connected with it, too much attention cannot be given to them. For instance, if the hose be not made of a good material and properly stitched, it will allow the escape of some of the powder of the train, both in its transport to the mine, and in laying it; and from either circumstance the most fearful accidents might happen. Again, in placing the powder in the hose, the utmost care is necessary to fill it properly; so that on the one hand it shall not be made to contain so much powder as to render it liable to burst, and on the other, that however handled and laid, there may be no part of the box without its due proportion of powder.

The Officer in charge of a mine should demand, in writing, from the Engineers' park or stores, the quantity of casing tubes, &c., and should fit them to the gallery and branches before he sends for the powder. The whole of the persons employed in the loading should be without shoes, and should be supplied with a pair of worsted stockings, such as are worn by fishermen.

On the arrival of the charge, all the miners and lights should be ordered out of the gallery and branch. The non-commissioned officer of the mine then advances with the charge, which should be placed in a copper-fastened truck with copper wheels, or wooden wheels having copper tires. On the top of the charge the hose or fuse should be coiled.

At the distance of about 20 feet the Officer will follow, carrying a strong reflecting lamp, and accompanied by an assistant. By this lamp a light is thrown on the gallery in front of the truck. On reaching the chamber, the Officer hands the lamp to his assistant, and then proceeds to direct the placing of the charge and the laying of the hose. This latter must be secured in a casing tube, the lid of which should be pegged down, and immediately afterwards covered over with 6 inches of mould. In doing this, a copper shovel should be used. After the charge is placed in the chamber, the Officer should satisfy himself that the hose is firmly fixed. The lamp is on no account to be at any time closer than 20 feet from the powder. It is necessary to lay down some such rule as this, without which there will be no security.

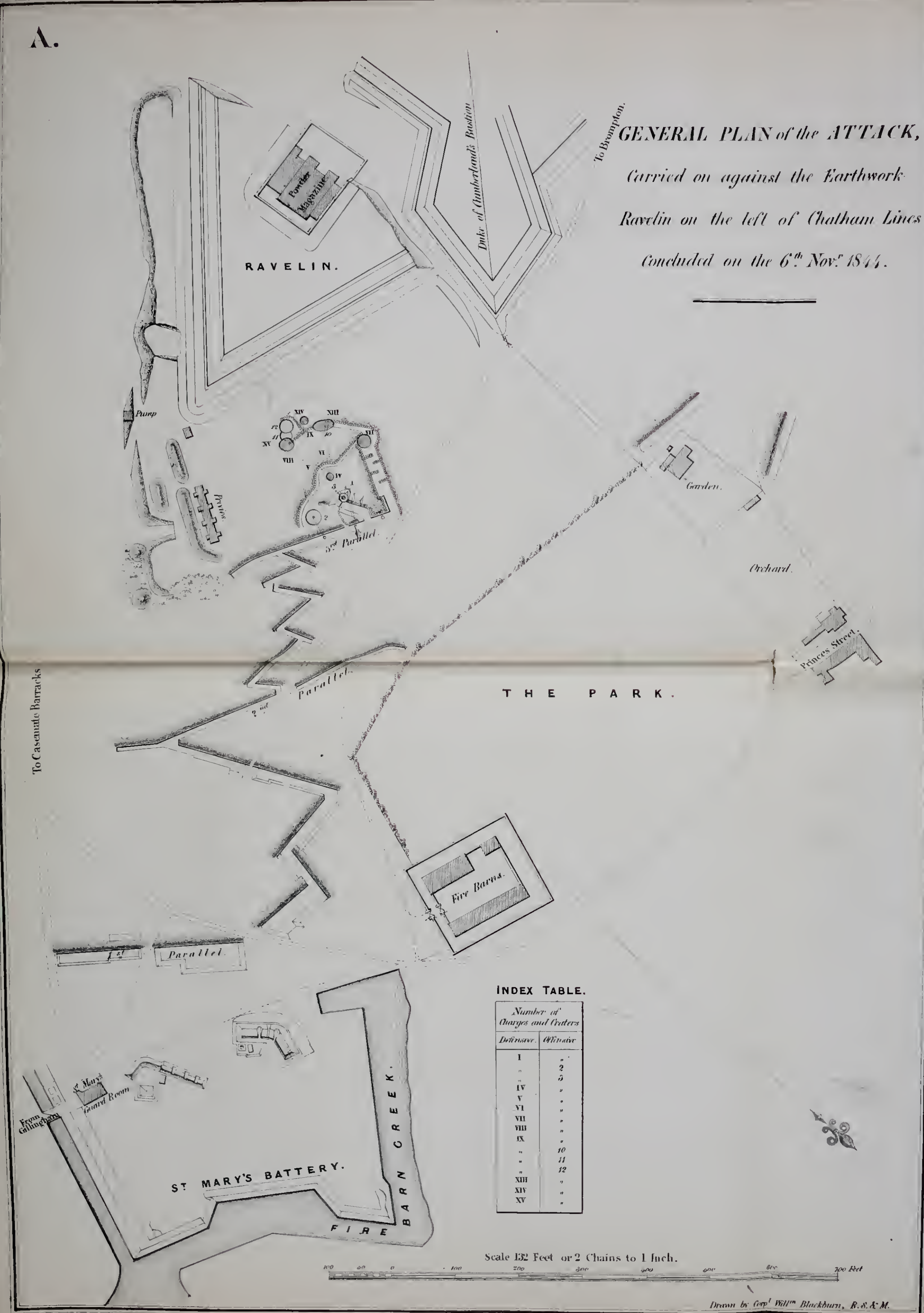
If trucks are required in tamping, they should be copper, fastened like those used for the conveyance of the charge; and if any work with the pick should be necessary near the powder, it must be performed with a brass pick, or brass push-pick.

On the tamping being complete, and orders given for preparing to fire, the Officer in charge should fix the portfire in the mouth of the priming powder hose, taking especial care that the inner end of the portfire is inserted ½ an inch into the powder, and that it is tied so firmly to the mouth of the hose, that it can neither be drawn out without violence, nor admit of the escape of any grains of powder from the hose. The end of the portfire which is to be lighted should be surrounded with clay, to prevent any part of the hose being exposed to sparks from it, till the whole of the portfire is burnt out; otherwise the firing Officer would be liable to risk.

As the workmen are often inclined to loiter in the galleries, when the charge is to be fired, the roll should be called on the outside of the mines, to ascertain whether all are present, before the portfire is lighted.

A.

GENERAL PLAN of the ATTACK,
Carried on against the Earthwork
Ravelin on the left of Chatham Lines
Concluded on the 6th Nov.r 1844.



INDEX TABLE.

Number of Charges and Craters	
Defensive.	Offensive
I	„
„	2
„	3
IV	„
V	„
VI	„
VII	„
VIII	„
IX	„
„	10
„	11
„	12
XIII	„
XIV	„
XV	„

Scale 132 Feet or 2 Chains to 1 Inch.

Drawn by Corp.l Will.m Blackburn, R.S. & M.

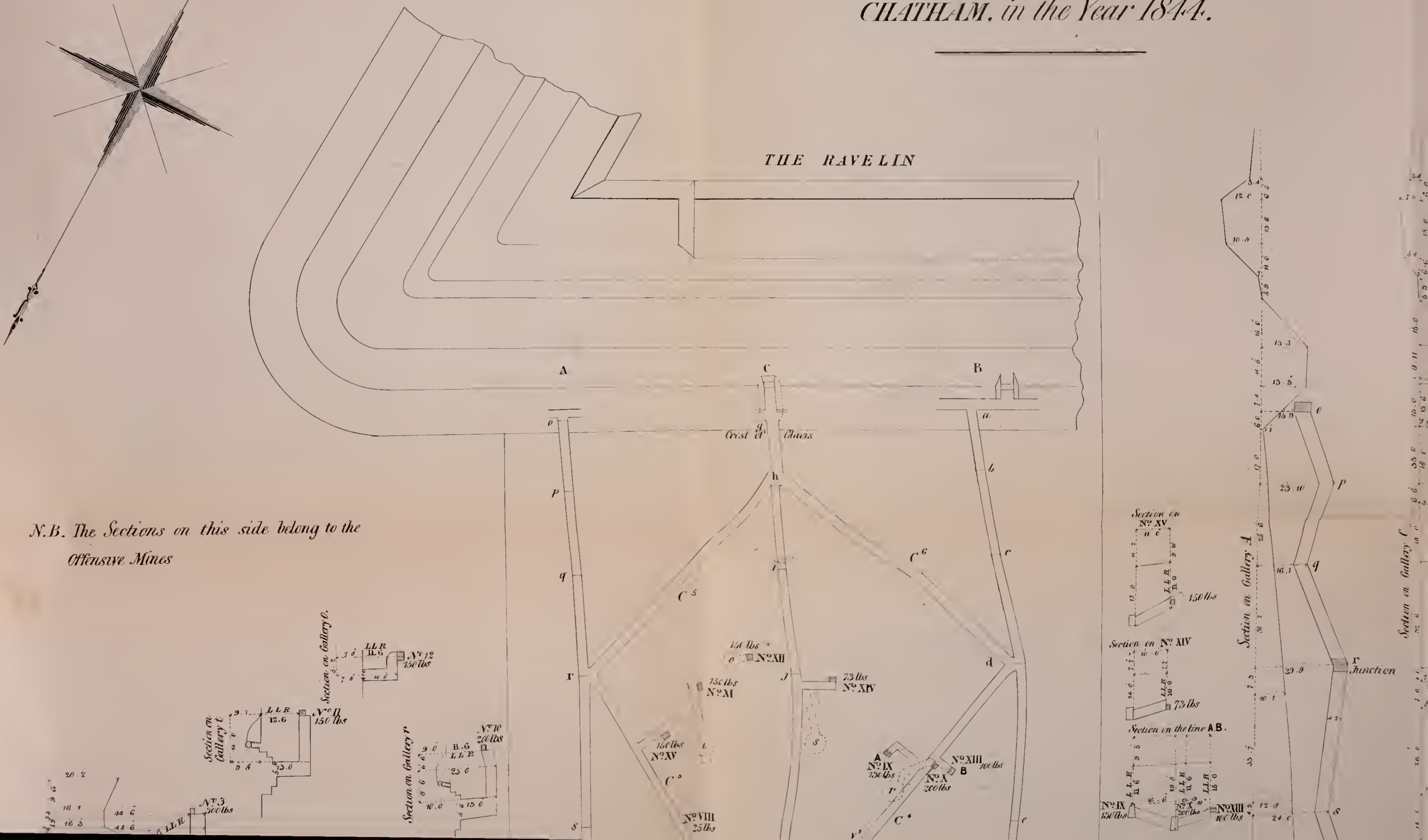
London. Published October 1845, by John Weale, Architectural Library, 59, High Holborn.

C

PLAN AND SECTIONS of the MINING OPERATIO

Carried on at the ROYAL ENGINEER Establishment.

CHATHAM, *in the Year 1844.*

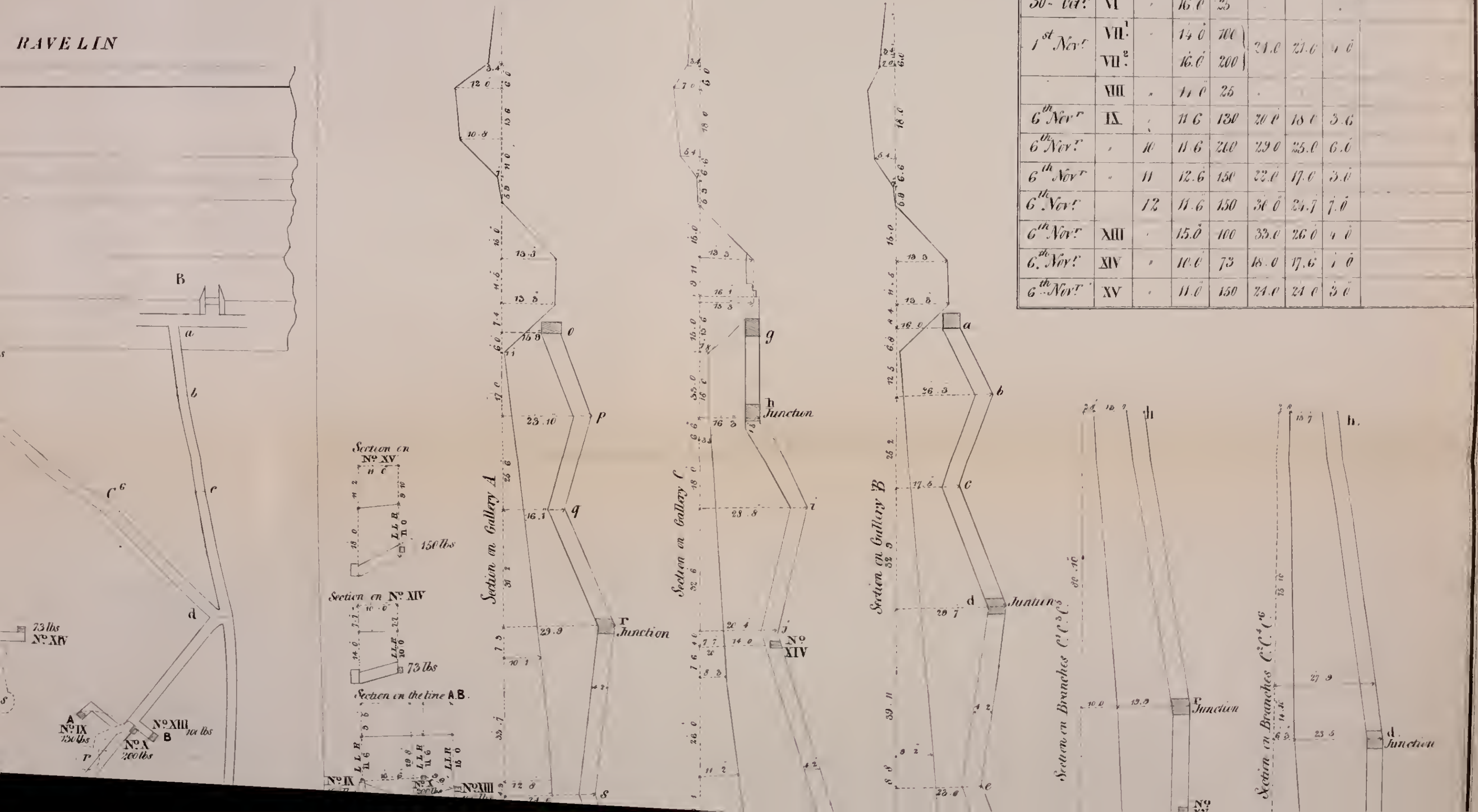


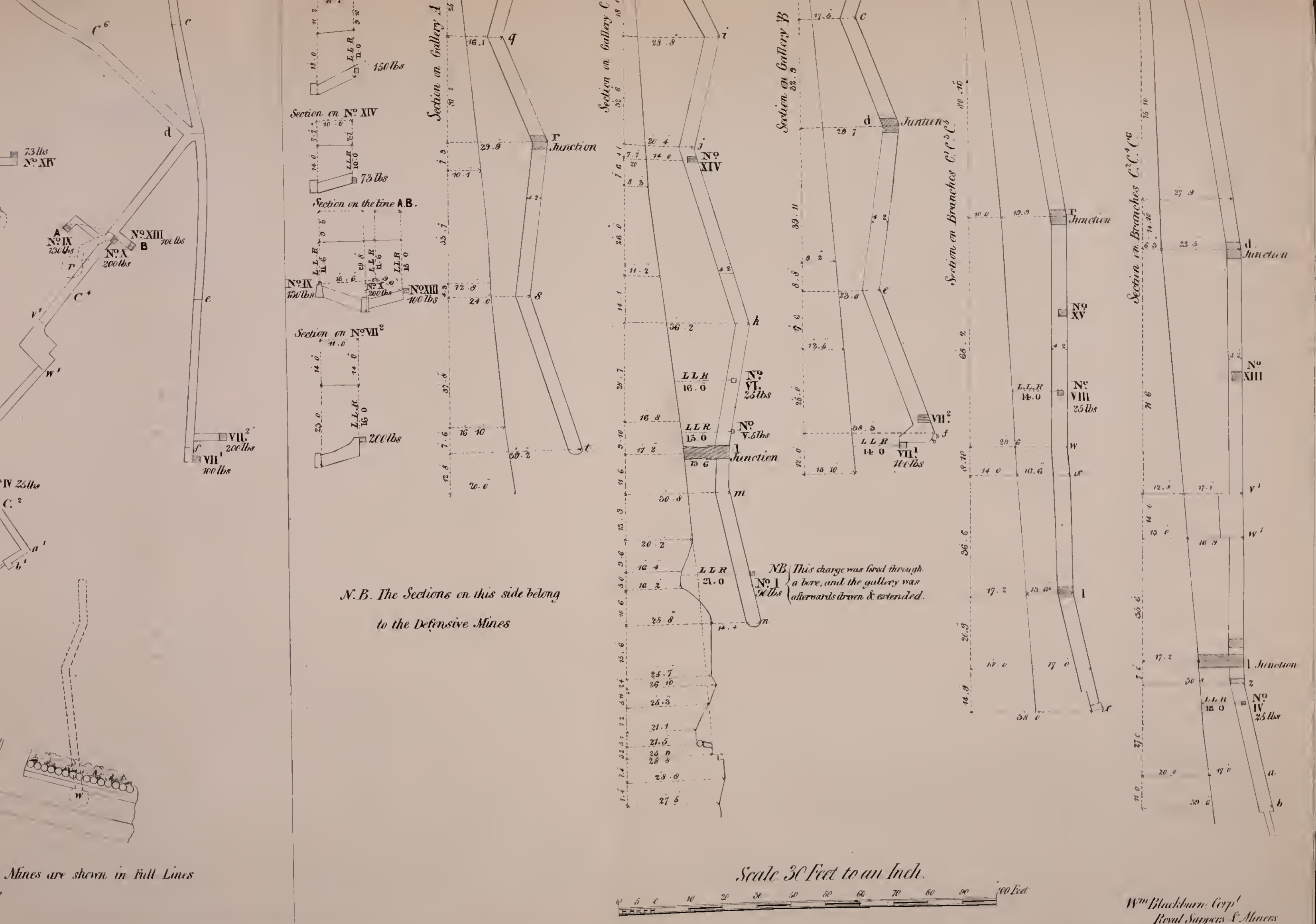
N.B. The Sections on this side belong to the Offensive Mines

ECTIONS of the MINING OPERATIONS,
on at the ROYAL ENGINEER Establishment.
CHATHAM, in the Year 1844.

Table to elucidate the Plan.

Date 1844.	No of Crater		Lines of least Resistance	Pounds of Powder	Size of Crater			REMARKS.
	Defensive	Offensive			Length	Breadth	Depth	
22nd Octr	I	.	21 0	90	5 0	5.0	2 0	
25th Octr		2	16 0	300	25.0	25 0	5 0	
26th Octr	,	3	20.0	300	15 0	15 0	4 0	
29th Octr	IV	.	13 0	25	12 0	12 0	2.6	
30th Octr	V	"	15 0	5		.	.	
30th Octr	VI	,	16.0	25			.	
1st Novr	VII1 VII2	.	14 0 16.0	100 200	21.0	21.0	4 0	
	VIII	,	14 0	25	.			
6th Novr	IX	,	11 6	130	20 0	18 0	3.6	
6th Novr	,	10	11 6	240	29 0	25.0	6.0	
6th Novr	"	11	12.6	150	22.0	17.0	3.0	
6th Novr		12	11.6	150	30 0	24.7	7.0	
6th Novr	XIII	.	15.0	100	33.0	26 0	4 0	
6th Novr	XIV	,	10.0	73	18.0	17.6	7 0	
6th Novr	XV	.	11.0	150	24.0	24 0	3 0	





N.B. This charge was fired through a bore, and the gallery was afterwards driven & extended.

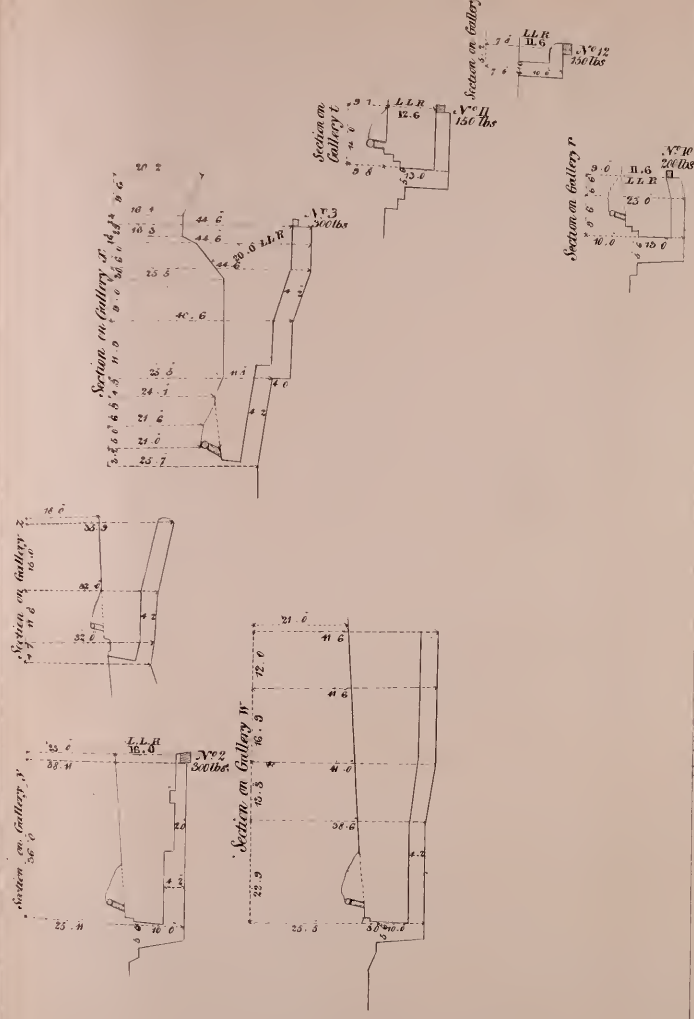
N.B. The Sections on this side belong to the Defensive Mines

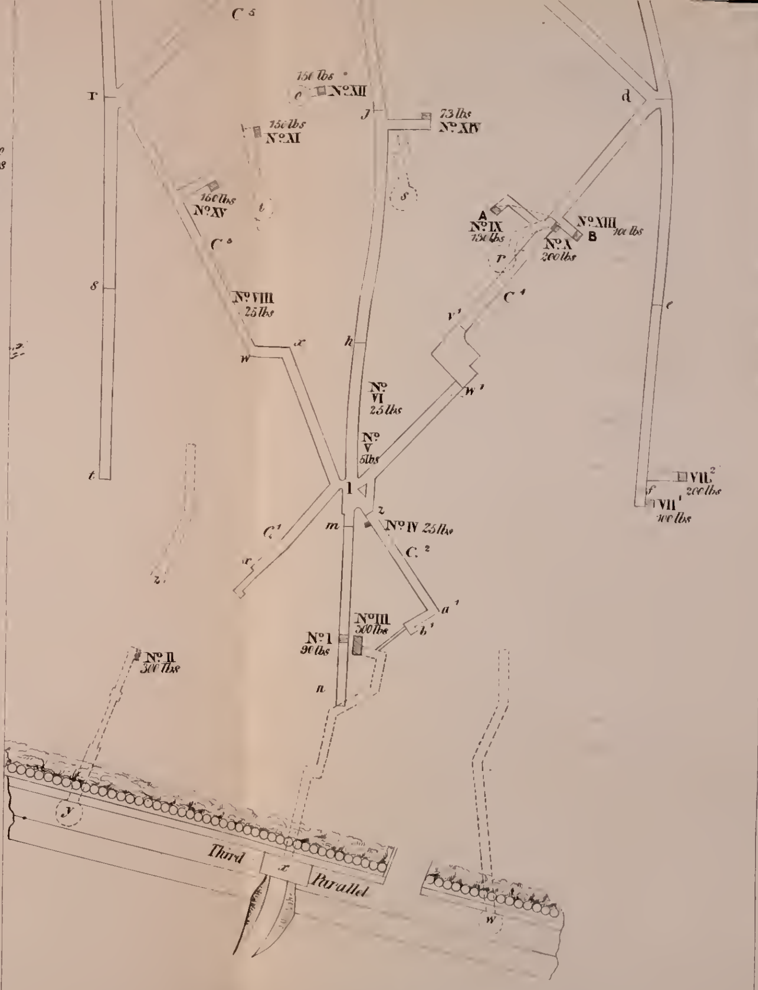
Mines are shewn in Full Lines

Scale 30 Feet to an Inch.

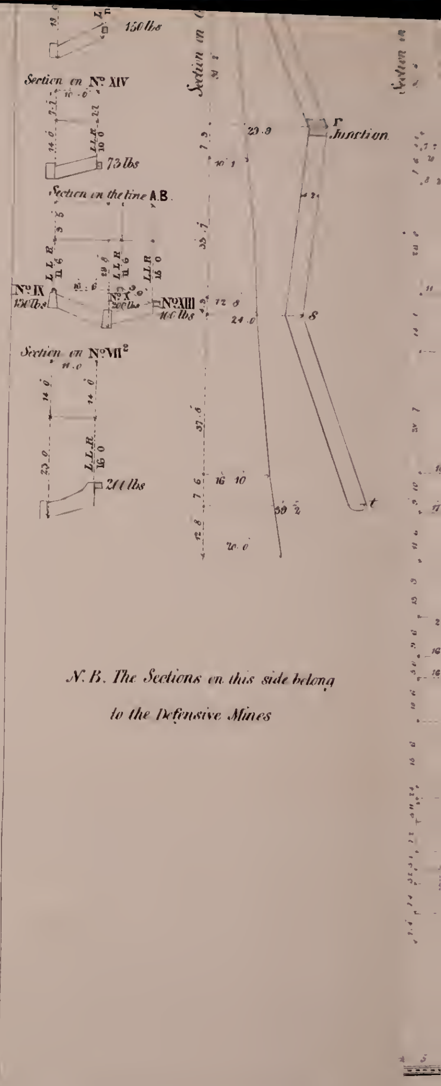
Wm Blackburn Corpl
Royal Sappers & Miners

ondon, Published October 1845, by John Weale, Architectural Library, 59, High Holborn.





N. B. In the above Plan the Defensive Mines are shewn in Full Lines
The Offensive Mines are Dotted



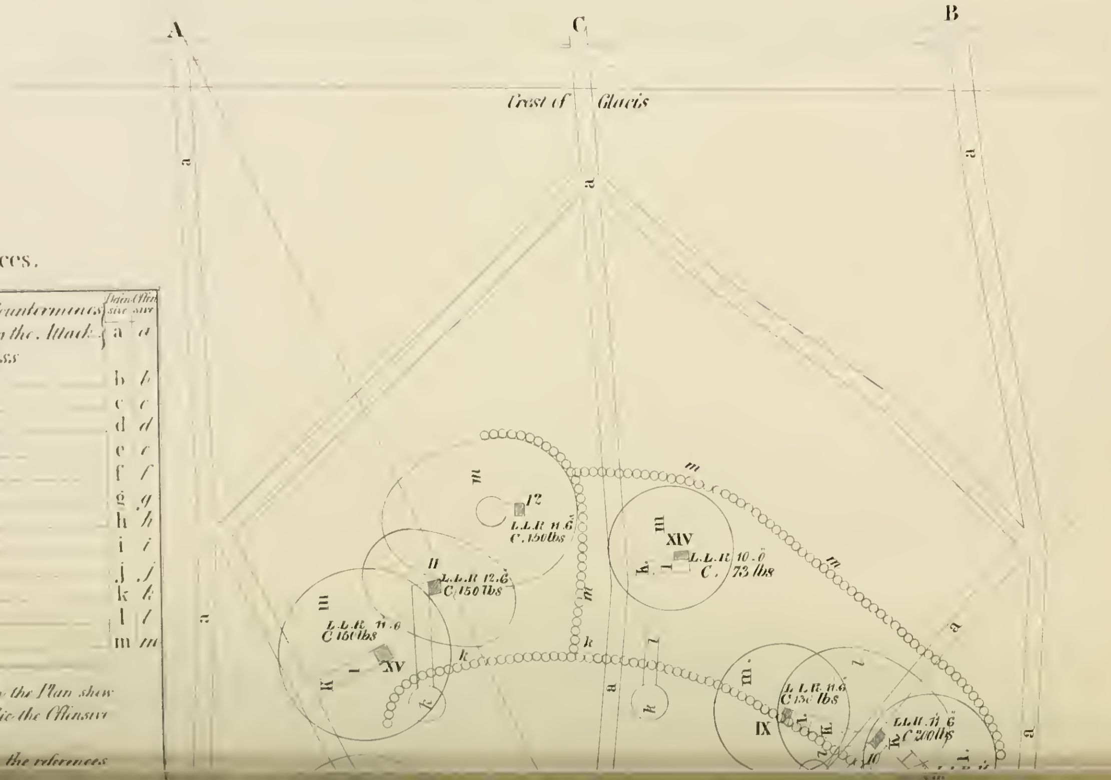
N. B. The Sections on this side belong
to the Defensive Mines

London, Published October 1845, by John Weale, Architectural Library, 59, High Holborn.

B

PLAN

Shewing the Attack and Defence of a System of Countermines, constructed under the Glacis, in front of the left face of the Ravelin, covering the Duke of Cumberland's Bastion, Chatham Lines, during the Months of October & November; 1844.



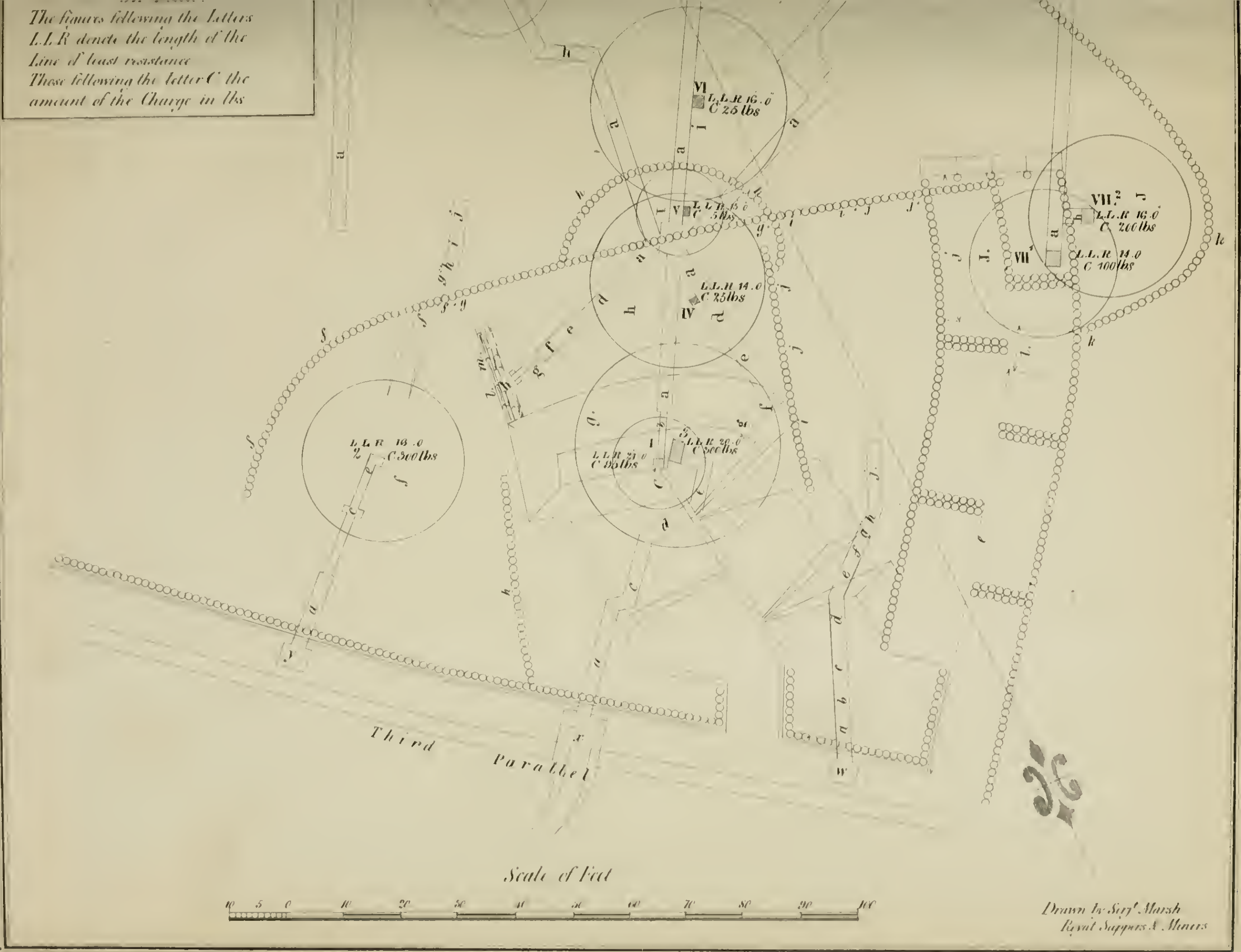
References.

	Defensive	Offensive
State of Mines and Countermines immediately preceding the Attack	a	*a*
Progress		
21st October	b	*b*
22nd do	c	*c*
23rd do	d	*d*
24th do	e	*e*
25th do	f	*f*
26th do	g	*g*
29th do	h	*h*
30th do	i	*i*
1st November	j	*j*
4th do	k	*k*
5th do	l	*l*
6th do	m	*m*

The Roman figures on the Plan shew the Defensive the Italic the Offensive Mines.

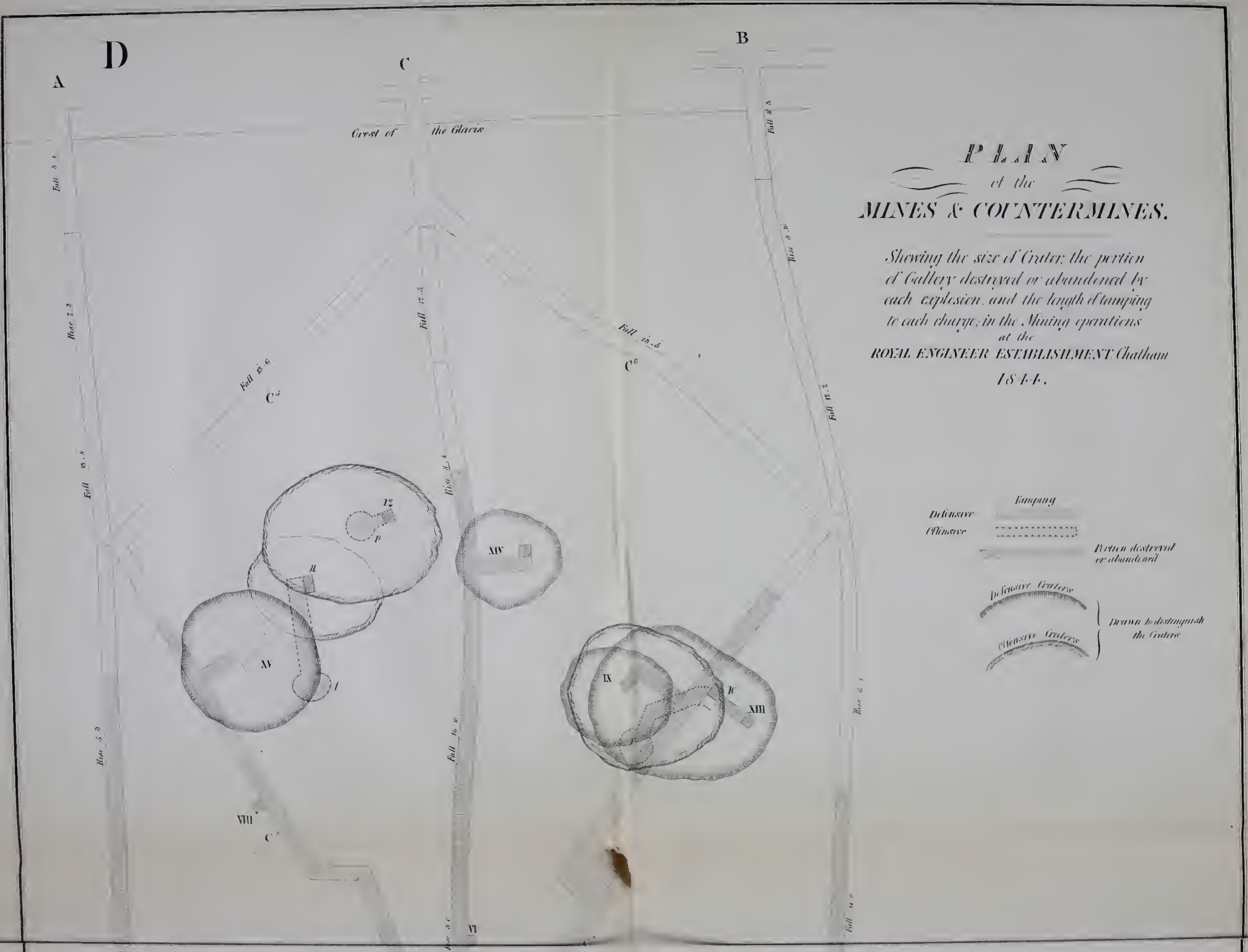
The Italic Letters in the references

The figures following the Letters L.L.R denote the length of the Line of least resistance
These following the letter C the amount of the Charge in lbs



Drawn by Serjt. Marsh
Royal Sappers & Miners

London. Published October 1845, by John Weale, Architectural Library, 59 High Holborn.

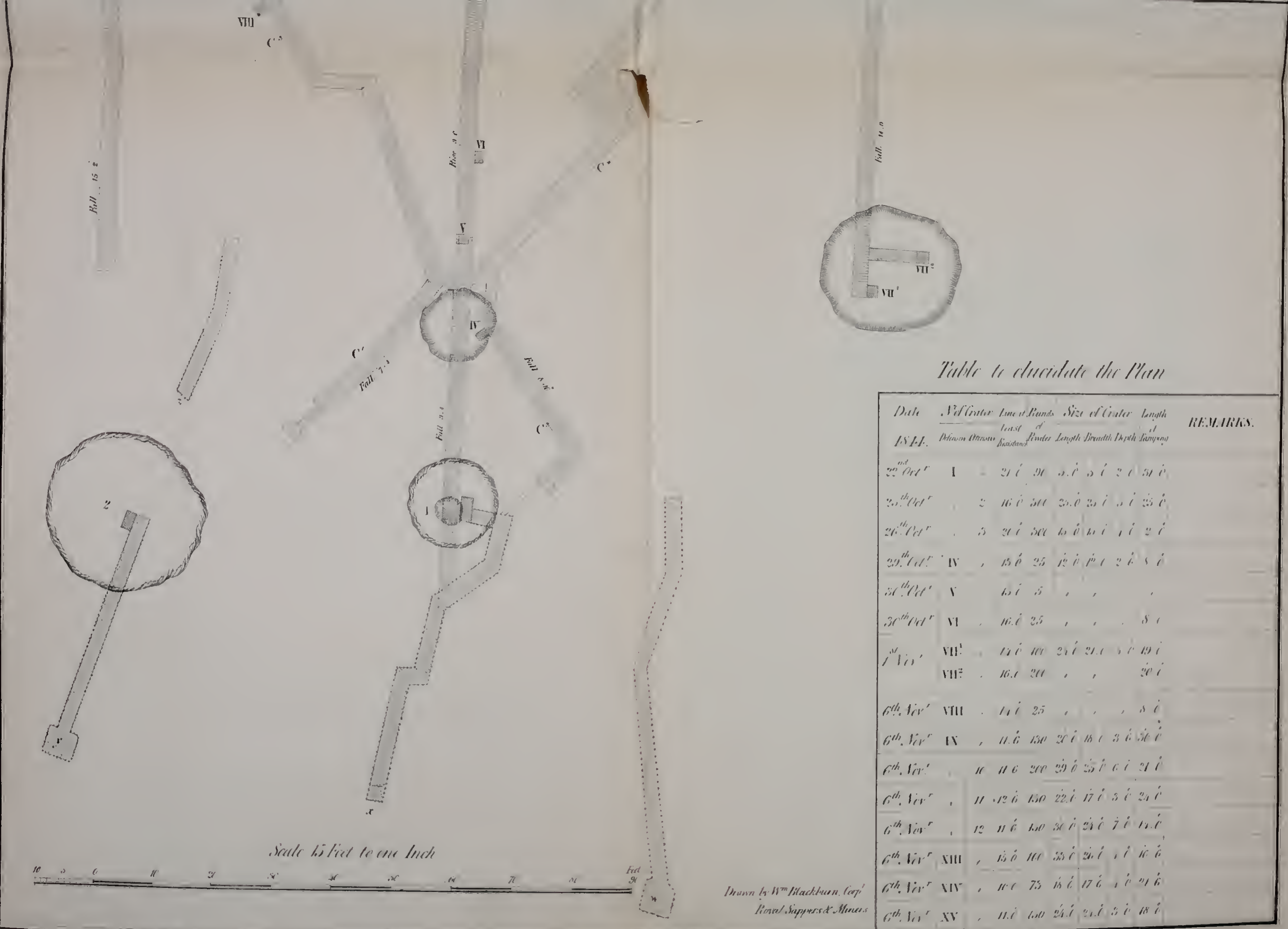


PLAN
of the
MINES & COUNTERMINES.

Shewing the size of Crater; the portion of Gallery destroyed or abandoned by each explosion, and the length of tamping to each charge; in the Mining operations at the

ROYAL ENGINEER ESTABLISHMENT *Chatham*

1844.



Scale 15 Feet to one Inch

Drawn by Wm Blackburn, Corpl
Royal Sappers & Miners

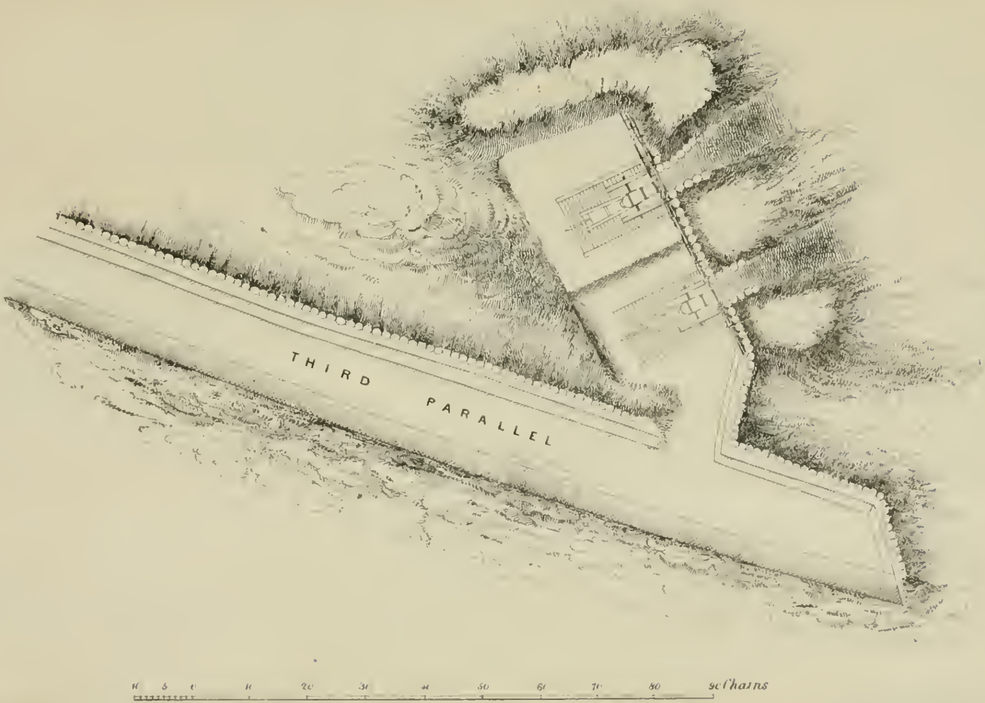
Table to elucidate the Plan

Date 1844.	No of Crater: Defensive	No of Crater: Offensive	Line of least Resistance	Pounds of Powder	Size of Crater: Length	Size of Crater: Breadth	Size of Crater: Depth	Length of Tamping	REMARKS.
22nd Octr	I	—	21.0	90	5.0	5.0	2.0	31.0	
25th Octr	,	2	16.0	500	25.0	25.0	5.0	25.0	
26th Octr	,	3	20.0	500	15.0	15.0	4.0	2.0	
29th Octr	IV	,	13.0	25	12.0	12.0	2.0	8.0	
30th Octr	V		13.0	5	,	,		,	
30th Octr	VI	,	16.0	25	,	,	,	8.0	
1st Novr	VII1	,	14.0	100	24.0	21.0	5.0	19.0	
	VII2	,	16.0	200	,	,		20.0	
6th Novr	VIII	,	14.0	25	,	,	,	8.0	
6th Novr	IX	,	11.6	130	20.0	18.0	3.6	56.0	
6th Novr	,	10	11.6	200	29.0	25.0	6.0	21.0	
6th Novr	,	11	12.6	150	22.0	17.0	3.0	24.0	
6th Novr	,	12	11.6	150	30.0	24.0	7.0	14.0	
6th Novr	XIII	,	15.0	100	35.0	26.0	4.0	16.6	
6th Novr	XIV	,	10.0	75	18.0	17.6	4.0	21.6	
6th Novr	XV	,	11.0	150	24.0	24.0	3.0	18.0	

London Published October 1845 by John Weale Architectural Library, 59, High Holborn.

No. 1.

PLAN shewing the **STATE** of the **UPPER GROUND WORKS** in front of the **3RD PARALLEL** on the 20th Octr 1844. in the attack carried on against the Earth Work Ravelin on the left of **CHATHAM LINES**, concluded on the 6th Novr 1844.



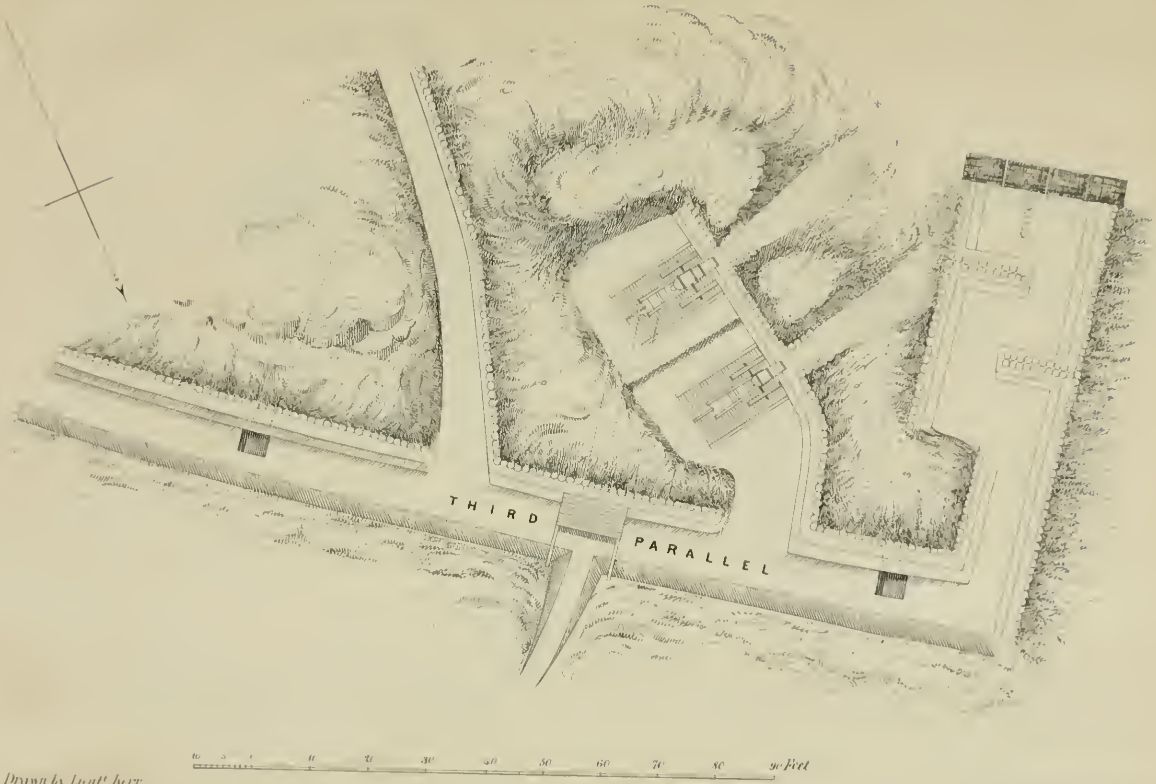
Drawn by Lieutt Du Can
Royal Engineers

C F Cheffins. Litho. London

London. Published. October. 1845. by John Weale. Architectural Library. 59. High Holborn

No. 2.

PLAN shewing the **STATE** of the **UPPER GROUND WORKS** in front of the **3RD PARALLEL** on the 23rd Oct^{r} 1844.



Drawn by Lieu^{t} Kerr.
Royal Engineers

C F Cheffins, Litho London

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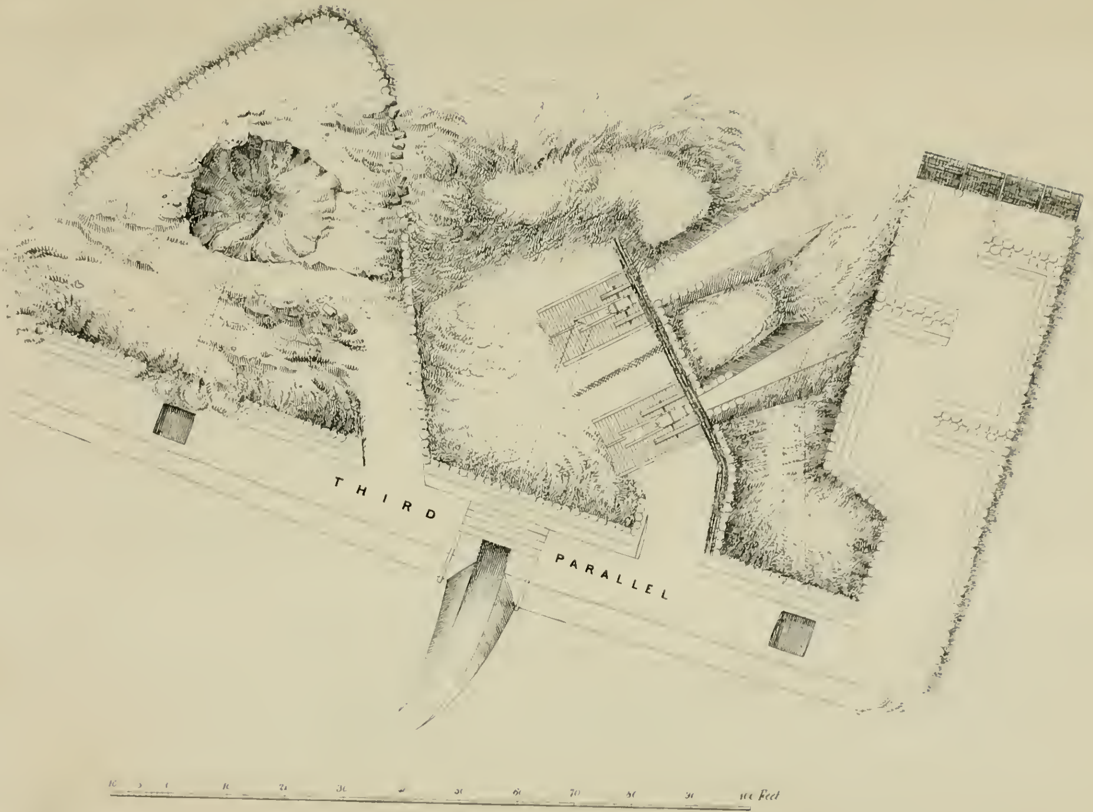
Nº 3.

PLAN shewing the **STATE** of the **UPPER GROUND WORKS** in front of the **3RD PARALLEL** on the 25th Octr 1844.



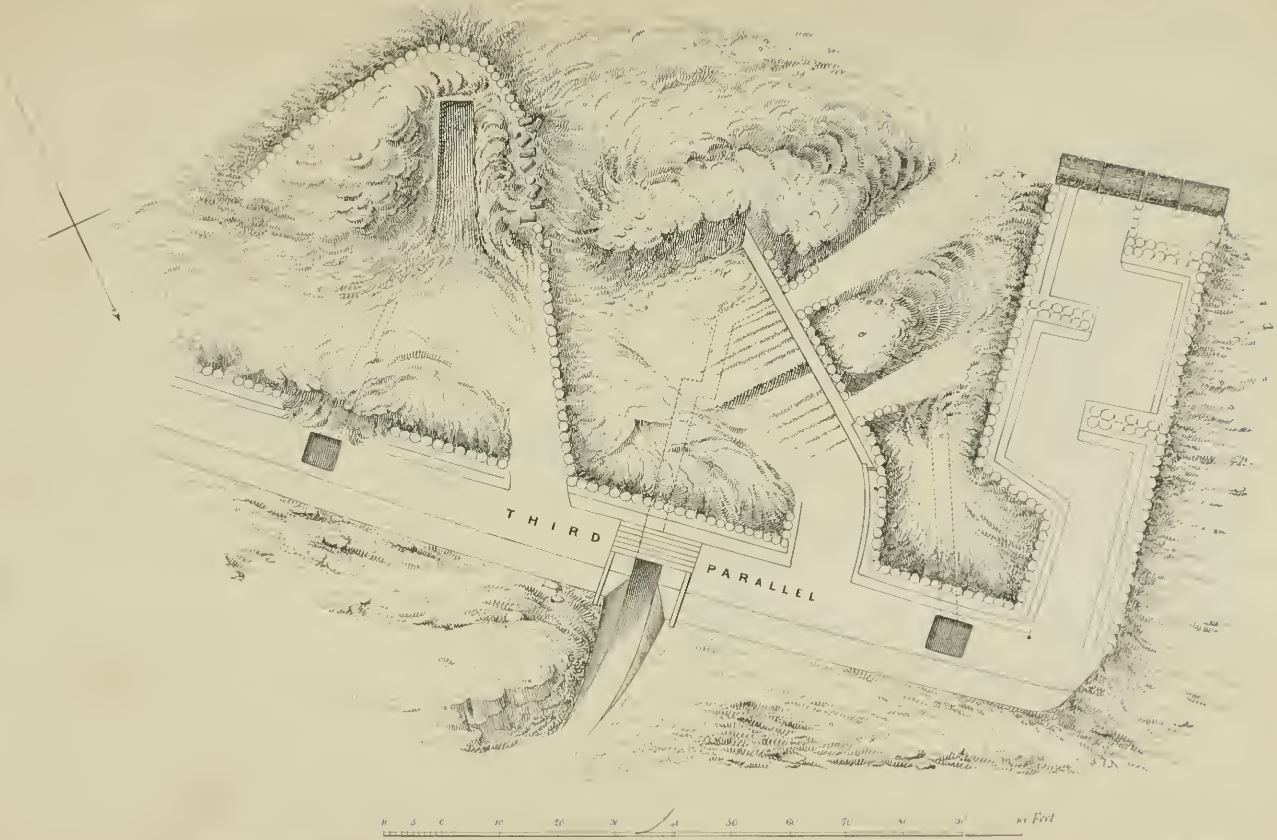
Drawn by Lieut Rie
Royal Engineers

C F Cheffins Lith. London

London. Published. October. 1845, by John Weale. Architectural Library. 59. High Holborn.

Nº 4.

PLAN shewing the STATE of the UPPER GROUND WORKS in front of the 3RD PARALLEL on the 26th Octr 1844.



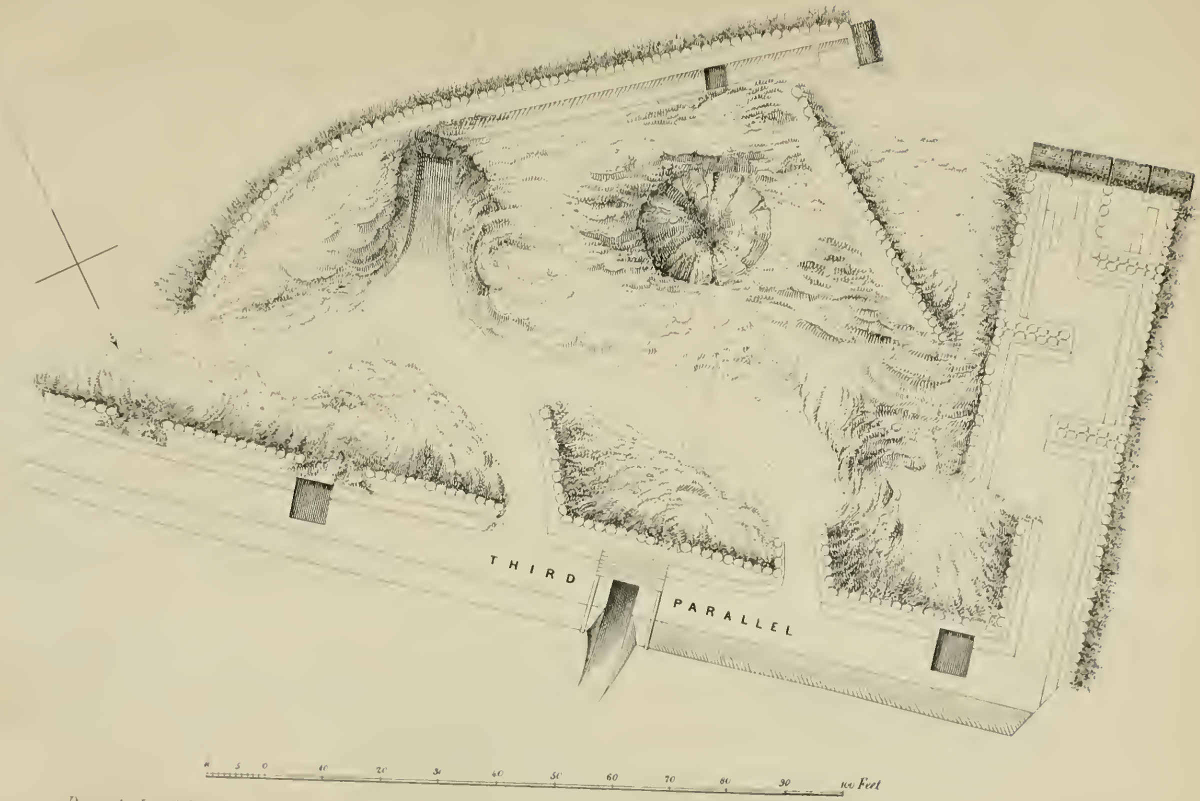
Drawn by Lieutt Moggridge
Royal Engineers.

C. F. Cheffins, Litho. London

London. Published October 1845. by John Weale, Architectural Library. 59, High Holborn.

No. 5.

PLAN shewing the STATE of the UPPER GROUND WORKS in front of the 3RD PARALLEL on the 26th Octr 1844.



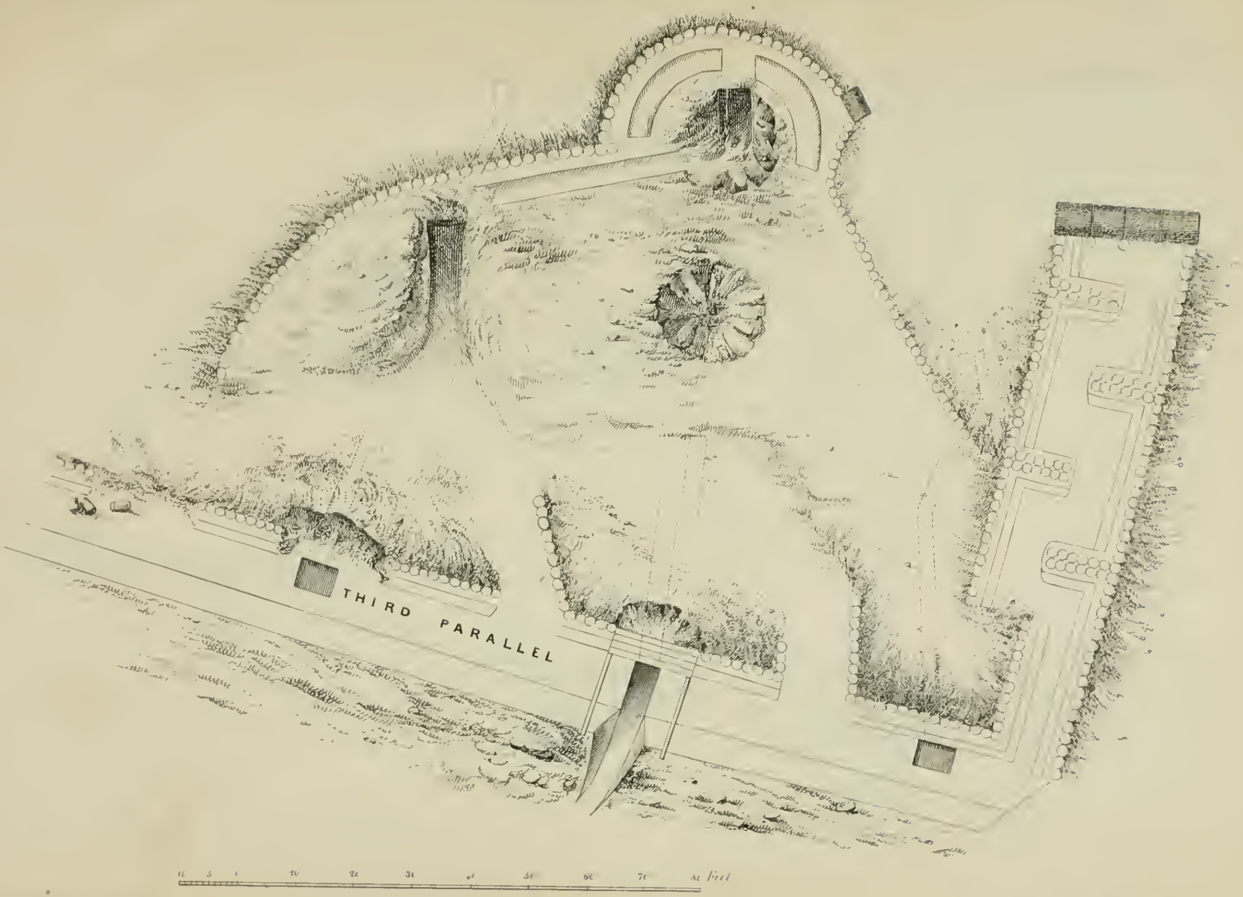
Drawn by Lieutt Stokes,
Royal Engineers

C F Cheffins, Litho London

London Published October 1845, by John Weale, Architectural Library, 59, High Holborn

No 6.

PLAN shewing the STATE of the UPPER GROUND WORKS in front of the 3RD PARALLEL on the 20th Octr 1844



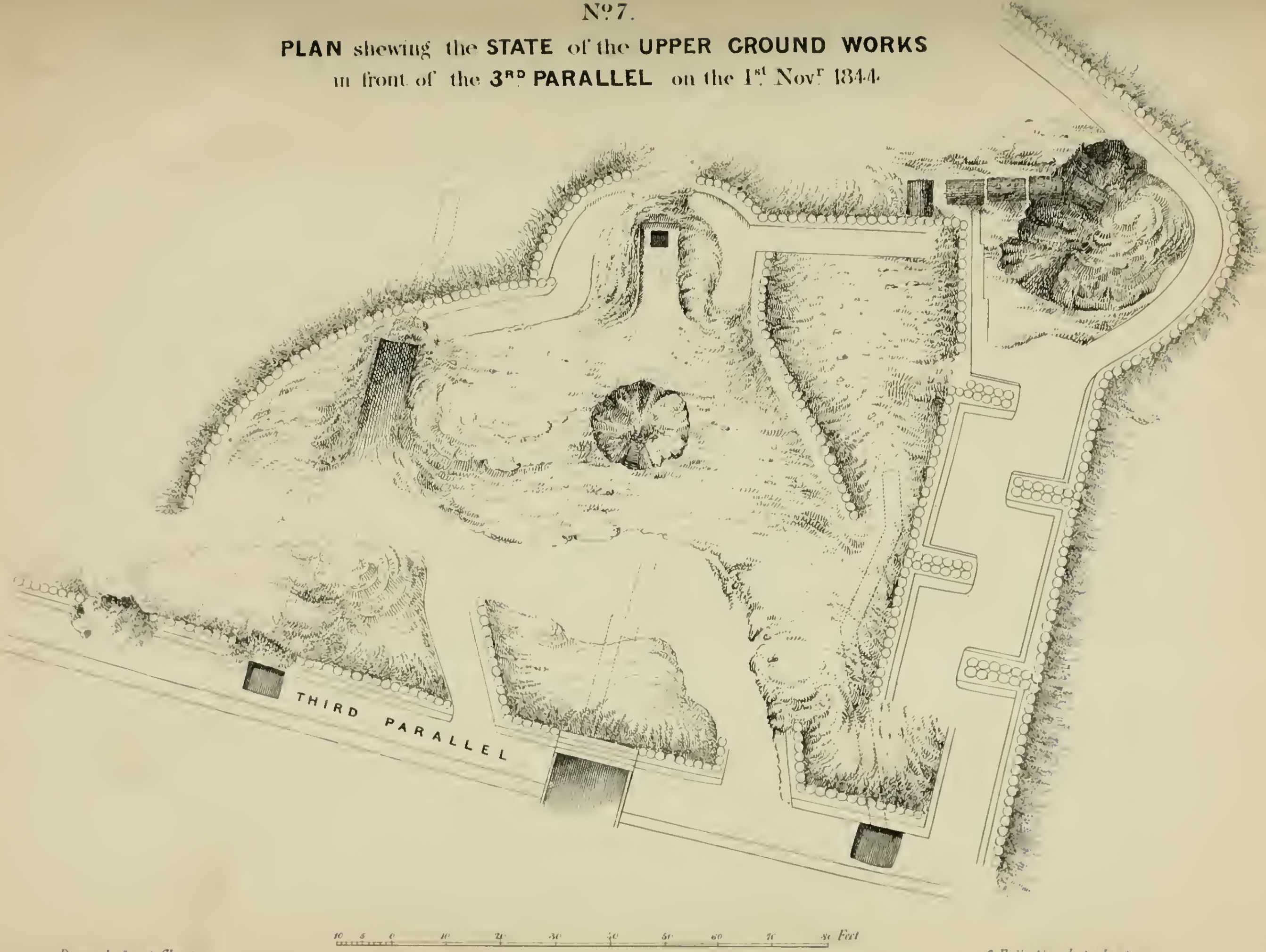
Drawn by Lieut Wray,
Royal Engineers

C F Cheffins Lith. London

London, Published October, 1845, by John Weale, Architectural Library, 59, High Holborn.

N° 7.

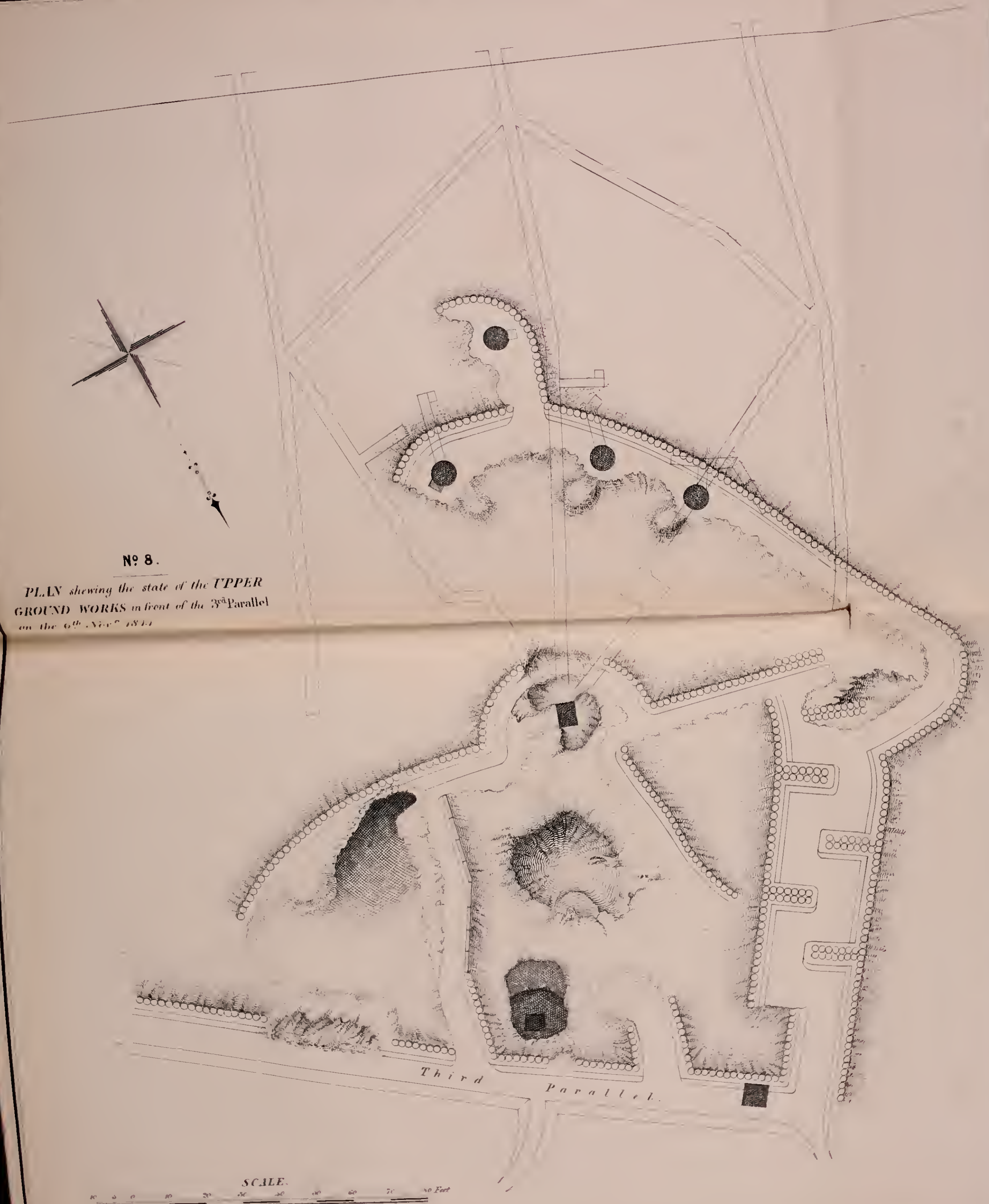
PLAN shewing the **STATE** of the **UPPER GROUND WORKS** in front of the **3RD PARALLEL** on the 1st. Novr. 1844.



Drawn by Lieut. Clarke.
Royal Engineers

C F Cheffins, Lithr. London

London, Published, October. 1845, by John Weale, Architectural Library, 59, High Holborn.



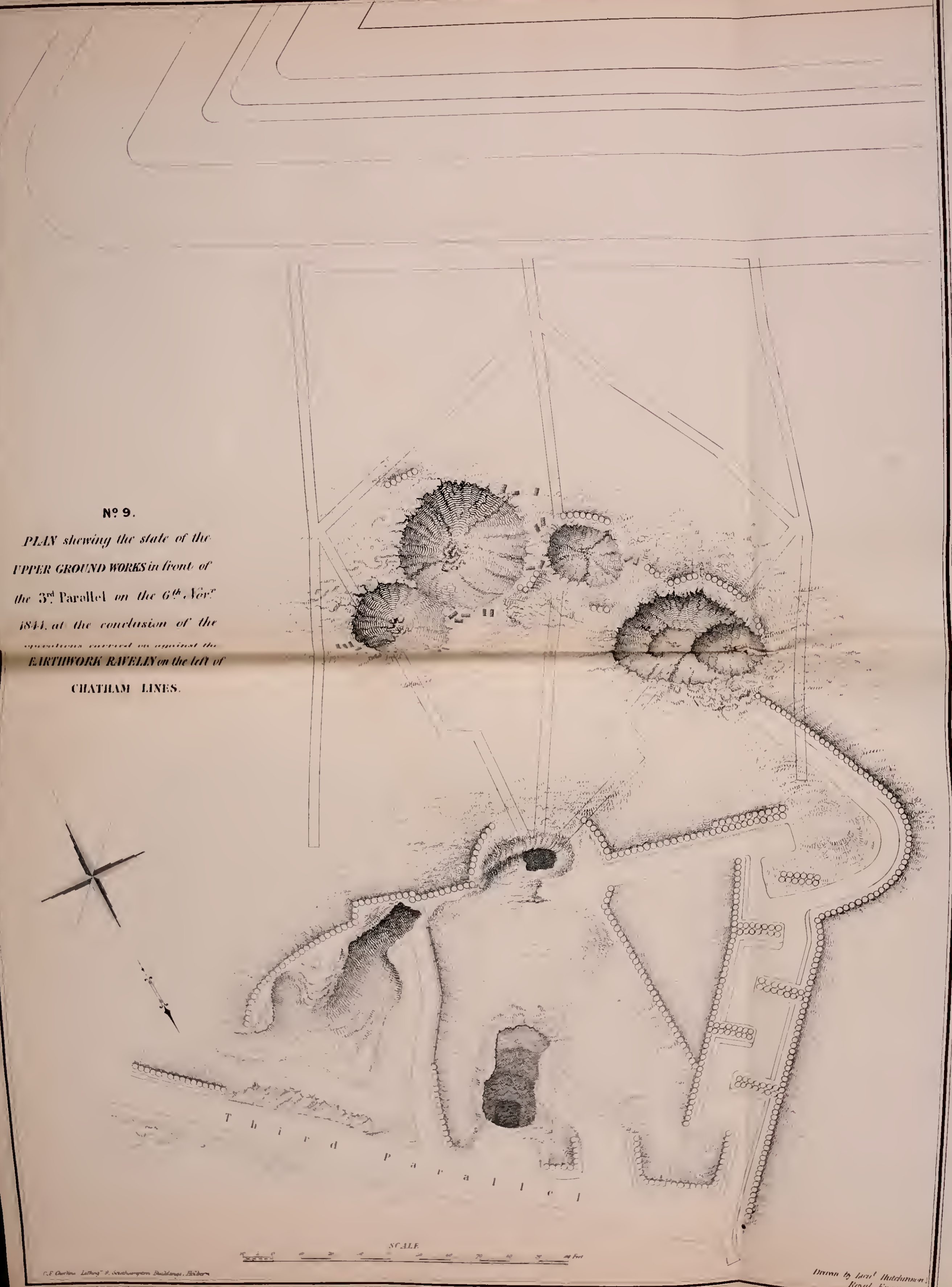
Nº 8.

PLAN *shewing the state of the* UPPER GROUND WORKS *in front of the* 3rd Parallel *on the* 6th Novr 1844

Drawn by ... S. March, Royal S. & M.

J. Chevalier, Lithog. ... Southampton Buildgs Holborn

London, Published October, 1845 by John Weale, Architectural Library, 59, High Holborn.



Nº 9.

PLAN shewing the state of the
***UPPER GROUND WORKS** in front of*
the 3rd Parallel on the 6th Novr
1844, at the conclusion of the
operations carried on against the
***EARTHWORK RAVELIN** on the left of*
CHATHAM LINES.

C.F. Cheffins Lithogr 9, Southampton Buildings, Holborn

Drawn by Lieut Hutchinson, Royal Engineers

[illegible] Published [illegible] by John Weale, Architectural Library, 59 High Holborn.

APPENDIX TO THE PRECEDING PAPER.

This Paper contains some suggestions on a few subjects connected with Military Mining, which were put in practice during the mining operations carried on at the Royal Engineer Establishment at Chatham, in the autumn of the year 1844.

On the most expeditious Method of placing a Charge of Powder in any required Position.

By Lieut. H. N. Penrice, *R.E.*

In all operations connected with military mining, whether in the attack or defence of a system of countermines, in blowing in the counterscarp, or in making a breach in the escarp of an enemy's works, the facility with which the gunpowder can be placed is an object of the greatest importance.

This has hitherto been found to be the most tedious operation connected with a siege, and one which can only proceed at a fixed rate, whatever may be the force which is available for its execution.

The great delay attending it has often been the cause of its not having been resorted to, and many lives have been sacrificed ineffectually in the assault of a work, which would have been an easy prey, had it been feasible to have exploded a charge under the point proposed to be assaulted.

The manner in which the mine or charge of powder has hitherto been placed is as follows:—

A small gallery 2 ft. 6 in. by 2 ft. is driven in the required direction, and of the proposed length; a small return or chamber is then made at the extremity of the gallery, for the reception of the charge. The gallery is tamped up again, the fuse connecting with the charge being carefully encased in wood, and fastened to the side of the gallery.

The following method is proposed as an improvement, and it is considered that it will materially expedite the operations of a military miner.

The principle of it is this,—that when a charge of powder is fired at the extremity of a bore, which is so effectually tamped as not to be opened by the explosion, the expansive gas which is created will compress the earth in the vicinity of the charge, forcing it back from the centre of ignition, until the resistance of the earth counterbalances the force of the expanded gas.

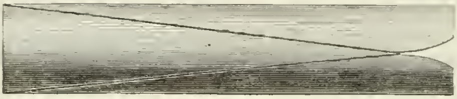
A chamber is thus formed at the extremity of the bore, capable of receiving a large charge directly the tamping bar is withdrawn.

A hole is accordingly bored in the required direction, and of the proposed length, with an iron auger of 3 or 4 inches diameter.

At the extremity of this place a small charge of powder,[1] in a tin case, with sufficient length of Bickford's fuse attached to it, to reach to the outside. The tin case should be in the shape of a conic frustrum, so as not to choke up the hole when pushed down it, and to enable it to go quite up to the end of the bore.

Should the soil be very loose, a copper tube should be passed down the bore directly the auger is withdrawn, to insure the passage being kept clear.

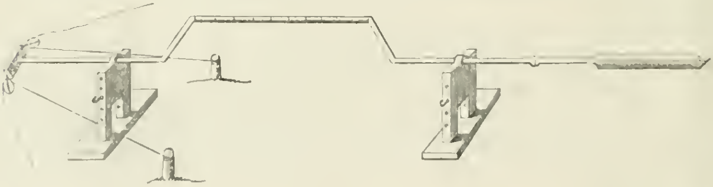
To tamp the bore, a solid iron bar (fitting the bore) should be placed next the charge, fastening lengths of the auger to this, so that the end of the tamping bar may reach to within about 4 feet of the mouth of the bore. The next 3 feet may be filled up with a cylinder of iron of the same diameter as the hole, the cylinder being composed of three wedges, and placed so that the butt end of the centre wedge being struck by the tamping bar, when the charge is fired, it is forced in between the other two, and this will effectually tamp the hole. A small groove is left in the two cylinders of iron, to allow room for the Bickford's fuse; and if the charge is in further than 15 feet, the fuse should be encased in a small tin tube, which may be permanently fastened to the cylinders. The explosion of this small charge forms a globe of compression for the reception of the large charge.



The tamping bar having been withdrawn, by clearing away some of the earth at the mouth of the bore, the chamber is loaded by passing bags, containing 1 lb. or upwards, down a copper tube, one having been previously put in, having Bickford's fuse attached. The tamping is executed as before, and the charge is then ready for firing.

The following apparatus was used when this method was tried at Chatham:

A crank to work the auger with, as shown in the accompanying sketch.



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[1] The size of the charge will of course depend on the required dimensions of the chamber. A charge of $1\frac{1}{2}$ lb. produced a chamber in the form of an ellipsoid, the larger axis being 32 inches, and the smaller one 20 inches, in soil weighing on the average about 107 lbs. to the cubic foot; but the tamping was not so complete as the method here described.

A $3\frac{1}{4}$-inch nose-bit auger, with 4-feet lengths.

An iron scraper.

A copper tube in 4-feet lengths, fitting in the same manner as a musket and bayonet.

A rope ramrod with a wooden head, the rope being encased in wooden cylinders, so as to be either stiff or flexible at pleasure.

A charge can be placed and fired by this method in about one-third of the time that it could be effected by the old method; and from the circumstance of there being so small a vent to the chamber, and the tamping being easier and more efficient, it is considered that the effect of the charge is increased by this method of placing it.

On the Form of the Mine Frame best adapted for the Construction of Galleries.

In most mining operations it is essentially necessary to combine the greatest expedition in driving the galleries with the amount of convenience, and the stability afforded by them, when completed. The form of the frames will be best deduced theoretically by considering the various conditions which they are required to fulfil.

In the 1st place, the frames should be high enough to give the miner a free use of his powers, and to allow him to pass along the gallery with comparative ease.

2ndly. They should be wide enough at the bottom to allow the passage of trucks with tools and materials along the gallery.

3rdly. The width at the top need not be greater than is sufficient for the shoulders of a man passing along the gallery.

The form resulting from this will be that of a trapezium.

Some frames were accordingly constructed of this form, equal in area to the large branch rectangular frame used in the Service (2 ft. 6 in. by 3 ft. 6 in.), the ground-sill remaining the same, viz., 2 ft. 6 in.; but the cap-sill was reduced to 1 ft. 9 in., thus getting an increase in height of 8 inches. The scantling was the same in each, viz., 2 inches.

Two galleries were then commenced in the escarp of the ditch of the ravelin in similar soil, weighing about 102 lbs. to the cubic foot.

The frames were placed 4 feet apart, with top and side sheeting, and at the end of $8\frac{1}{2}$ hours the distance driven in each gallery was as follows:

In gallery No. 1, with the rectangular frames, 11 ft. 6 in.
„ No. 2, with the trapezium frames, 16 ft. 3 in.

The workmen in gallery No. 1 were more detained by the falling of the earth from the top of the gallery while driving than in No. 2, as the excavation there was not so wide at the top, and consequently was of a more stable form.

The miners who worked with the new frames accounted for their increase in the distance driven from the following advantages:

That they were not so cramped in their work, as the additional height gained was of great advantage in using the pick, which is used vertically; that the greater part of the excavation was below their shoulders, thus getting rid of the picking in the upper right and left-hand corners of the rectangular frame, which was by far the most tedious and difficult part for a miner to excavate, on his knees, and entirely useless when completed, as the space there was unnecessary. The cap-sill was also much lighter and easier to fit, as in driving all small galleries it is held in one hand, while the other is employed in using the push-pick. Only one piece of top sheeting was necessary, instead of two. From the additional height, the convenience of clearing the earth away from the head of the gallery was increased.

Besides these advantages in driving, the strength of the cap-sill is considerably increased (where top sheeting is used), as the points of bearing are much closer, the cap-sills of the rectangular frames having been broken in two, in some instances, during the construction of the countermines, by the weight of the superincumbent earth. Should the gallery have been damaged in any way by an explosion or otherwise, these frames are very easily shored up from the nature of their form. A gallery of this form might be driven in some soils, with the frames at open order, with sheeting, where it would be necessary to use close casing with the rectangular frame, as the figure of the former excavation approaches nearer to that of an arch, or a form which would support itself, than the latter.

The experiment was not tried with the frames at close order, but as the cap-sill of the trapezium frame is easier to fix than the other, the difference in the expedition of driving the galleries would probably have been more apparent.

When the trapezium frames had been approved of, and were used in some of the galleries of the countermines, the miners were always required to drive $\frac{1}{3}$rd more with them than in other galleries, where they were using the frames that remained of the rectangular form.

I consider that a frame 5 feet 8½ inches high, with a cap-sill of 2 feet, and a ground-sill of 3 feet 6 inches (which is equal in area to the present rectangular gallery frame, 4 feet 6 inches by 3 feet 6 inches), is a size which will best combine expedition in driving with convenience afforded by the gallery when completed.[2]

An Instrument for Detecting the Approach of an Enemy's Miner on any Gallery belonging to the Besieged.

When a system of countermines is attacked by a besieging force, it is of great importance in the defence to be able to discover the approach of the besiegers' miners on any gallery as early as possible, in order to be able to oppose their subterraneous operations. The subject is therefore deserving of some attention, and too much accuracy and delicacy cannot be shown in obtaining the required results.

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[2] The scantling of the stanchions should be 3 inches.

The facility with which sound travels, or with which motion is communicated through any soil, will depend chiefly upon the specific gravity and tenacity of the soil. It is found to be communicated much better, and to a far greater distance, through a rocky stratum, than through heavy clay or sand.

Some of the French authors who have written large treatises on military mining, have stated, with regard to this subject, that peas placed on a drum on the floor of a gallery will indicate, by their motion, the proximity of miners at work. This is, however, entirely theoretical, for they can be detected by the ear long before they are in any way indicated in this manner.

I propose, by means of mercury, to effect an instrument which shall answer the required purpose; the oscillations on the surface of the mercury being so easily detected on the slightest motion.

Let small troughs of mercury be arranged in the *sides* of a regular polygon, a hexagon for instance, and let uprights, with small pieces of looking-glass attached to them, be placed in the *angles*.

The light of a wax taper being then thrown into one trough of mercury, will be reflected round the hexagon into the other five troughs. Let a hole be bored from the gallery in the supposed direction, and let a drum be suspended with iron wire to the end of the auger. Then place the troughs of mercury, arranged on a hexagon of wood, on the drum.

We will suppose that the distance at which the enemy is working is so great, that no jar or oscillation whatever is perceptible on the surface of the mercury. Then if the reflection of the flame of the taper be thrown into one of the troughs, the perception of the oscillation would be rendered doubly distinct, for the flame may be supposed to have been in reality in motion with each blow of the enemy's pick against the soil, as also the surface of the mercury: now therefore that the reflection of a moving object has been thrown into a moving medium, the motion will be doubled on the surface of the mercury.

If it is still imperceptible, the reflection of the flame into the next trough of mercury will treble the motion, and so on round the other four, till it becomes visible,—each additional reflection multiplying the motion.

By conducting this experiment with accuracy, a scale of distances might be determined in the soil in which the countermines are constructed.

When an instrument of this kind was used at Chatham in the galleries of the countermines to test its efficiency, the oscillation produced on the surface of the mercury by each blow of the pick was distinctly visible in the second trough, at a distance of 80 feet, through a soil the average weight of a cubic foot being about 109 ℔s. 4 oz.

H. N. Penrice,
Lieutenant, Royal Engineers.

Sheerness, May 20, 1845.

XVI.—*Report on a Survey of a Line for a Canal to unite the Bay of Fundy with the Gulf of Saint Lawrence, in* 1842.

TO HIS EXCELLENCY SIR WILLIAM M. G. COLEBROOKE, K. H., &c., &c., &c.

May it please your Excellency,

Plate LVI. 1. In obedience to your Excellency's commands, I proceeded, as soon after my arrival in this province, in July last, as I could make my arrangements, to the county of Westmoreland, to examine the several lines proposed for the route for a canal to unite the waters of the Bay of Fundy with those of the Gulph of Saint Lawrence, and have the honour to report the result of those examinations.

2. It is unnecessary for me to dwell upon the importance of an undertaking which seems in this province to be generally admitted. The duty of the engineer is to ascertain the practicability of the scheme, and having done so, to determine the best line, and frame an estimate of the expense.

3. The object of a canal to unite the waters above mentioned, is evidently to enable coasting or other vessels to pass from port to port, without the risk and delay incurred in navigating the Gulph of Saint Lawrence, and making almost the entire circuit of Nova Scotia. The dimensions of the canal must be determined by the object it is intended to effect.

4. An inspection of the charts of Bay Verte and Shediac Harbours, surveyed by Captain Bayfield, R. N. (copies of which have been kindly furnished me by Captain Owen, R. N.), will show, that from the shoalness of the waters, it will be necessary to carry a canal a considerable distance into the sea to insure 10 feet water at the neap flood tides. This would be a tedious and an expensive operation, particularly when the whole distance is always under water, as is the case in Shediac Harbour; and of course the deeper the canal is made, the farther it must be carried into the sea. This consideration limits me to what should be the minimum size for a canal which would in any degree answer the end proposed, namely, 45 feet at bottom and 85 feet on the water surface, for the width, with a depth of 10 feet water in the canal. One of larger dimensions would be preferable, if circumstances were favourable, but it is upon the above data I ground any calculations it may be necessary to make in the course of this Report. With these dimensions, vessels drawing 9 feet of water would pass through the canal and over the lock-sills, and the width is not too great to admit of two vessels

passing each other, especially steam vessels of the ordinary construction, whose paddle boxes occupy much room.

5. The first line I examined was from the confluence of the Au Lac and Tantamar Rivers, at the head of Cumberland Basin, to the Tignish River falling into Bay Verte. I proceeded along the Tantamar and Jolie Cœur Marshes to the source of the Au Lac River, thence to the Swamp, the source of the Missiguash River. I examined the ground on this spot particularly, and found the whole to be a floating morass, the surface composed of mosses and aquatic plants, the matted roots of which alone afford an insecure footing. Finding no firm bottom at depths varying from 6 to 12 feet, I considered that it might be less difficult and less expensive to cut through a more elevated tract of country, provided a sufficient supply of water could be obtained on the summit level, than to carry the embankments of a canal through these bogs, the shortest distance through which is one mile. I therefore kept along the low ground by the side, and to the head of the Portage Lake, the water level of which I found to be 4 feet 9 inches above the point of commencement, thence crossing the Bay Verte Road at the Portage Bridge, proceeded nearly along water courses, until I re-crossed the Bay Verte Road, directing my course to the Tignish River, and visiting in my route every stream that could possibly be made at all available for the supply of water for a canal. (This route is shown by a dotted line on Plan No. 1.) Plate LVII.

6. I examined the nature and capacity of the several streams, particularly those which run into the head of the Portage Lake, and find that they originate in small swamps; that to whatever degree they may be filled during the freshets, they are in the summer months so very inconsiderable that they do not furnish a sufficiency of water for working the several small saw-mills upon them. I consider from these circumstances that dependence cannot be placed upon them for the supply of water required for a canal of the dimensions stated in paragraph No. 4; nor am I aware of any other water available for the purpose on this line: the waters of the Portage Lake, even if sufficient, cannot be raised to the height required.

7. The same deficiency of water will hold good, if the route taken by Mr. Hall in 1825 were followed,—a route I believe to be the most level, and offering, with the exception of the bogs, few impediments.

8. This deficiency might be got rid of, or greatly simplified, by admitting the tidal waters of the Bay of Fundy, as proposed by Mr. Telford in his Report on Mr. Hall's Survey of 1825, wherein he suggests making the spring tides the summit level, if they were limpid and clear; but they are very turbid, and inadmissible from the quantity of earthy matter held in solution by them, of which a great deposit takes place, even in moving water, and which would in the still water of a canal accumulate to such an extent as soon to impede the working of the machinery of the locks, and cause frequent interruptions to the navigation for the purpose of cleansing the canal,—a measure fraught with inconvenience and considerable expense.

9. The locks for such a work should not be less than 150 feet between the gates, and 40 feet wide: the quantity of water required to fill such a lock, and which would be expended every time a vessel was passed through, is 60,000 cubic feet, or 374,296 gallons.

10. The levels taken by me being merely trials, and not necessary to elucidate my Report upon this route, I have judged it better not to exhibit them on paper, as they might possibly mislead, and create an erroneous opinion as to the general level of the country.

11. On the left or north side of the road from Sackville to Bay Verte, separated from the Jolie Cœur Marsh by a ridge of land, are several small lakes, and it has been suggested that they might be made available for the supply of water. I ran a level from the Jolie Cœur Marsh to one of them, and found the water 2 feet 8 inches *lower* than the marsh. These lakes are of course influenced by the spring freshets, but the outlet, by which the superfluous water finds its way to the sea, does not indicate that any great body of water passes through at any time, and they are on too low a level to supply the head-water for a canal.

Plate LVIII. Plan No. 2.

12. The second line which came under examination was from Shediac Harbour to the Bay of Fundy, commencing at the high-water mark, neap flood tide, at the bridge across the Scadouk River, and terminating at Dorchester Island, the distance being 25¼ miles.

13. I proceeded 1½ mile up the Scadouk River, and then turned up a very small creek, or rather brook, called Underwoods, which appeared to be the most eligible route by which a canal could be brought into connection with the Scadouk. I proceeded in a south-westerly direction, following nearly the course taken by Mr. Minnette in 1823, towards the marshy meadows and Cariboo Plain, through which the Scadouk takes a very winding course towards Shediac Harbour: crossing the river and low lands, which form a kind of basin, being surrounded on all sides by rising ground, I continued my course to the Memramcook River, passing in my way the sources of the Indian Stream which falls into the Memramcook nearly 1 mile above the point where I crossed that river. Turning more southerly, I followed the course of the Memramcook nearly all the way to where it debouches into the Bay of Fundy at Dorchester Island. My course is shown by a dotted line on plan No. 2.

14. I have shown in section the ground traversed between the Scadouk and Memramcook Rivers, sufficient, I hope, to elucidate the remarks I have to offer upon this route in reference to its adaptation for the line of a canal. The section shows the most elevated tract of country between Shediac Harbour and the Bay of Fundy.

15. It will be seen at one view, that to carry a canal by this route, it is necessary that there should be an ample supply of water upon this summit level, and that it must be looked for in the low ground or basin through which the Scadouk flows.

16. There appear to be two probable methods of creating this desideratum. The first is to dam up the Scadouk River where it enters the gorge, through which it flows on

leaving the Cariboo Plain, as at O, Plan No. 2, and thus raise the waters to such a height as to fill the canal and locks terminating the summit level. The second is to convert the water so raised by the dam at O, into a reservoir only, and not for purposes of navigation.

17. With reference to the first of these methods, admitting that the spring freshets would fill the canal to the extent required, in the first instance, the next point for consideration is, will the Scadouk River, uninfluenced by the freshets, maintain this supply during the summer months? for it is evident that unless a full supply is constantly kept up, so as to insure the depth of 9 feet over the lock-sills, vessels of the description for which this depth is calculated could not pass.

18. The current of the Scadouk River across the low ground, in the summer months, is scarcely perceptible; the width of the river is 33 feet, the depth averages 3 feet. Such dimensions with so small a velocity would afford a very insufficient accumulation of water, when not under the influence of the freshets; and even of this accumulation, the whole would not be available, because an allowance must be made for unavoidable leakage, and also for the effects of evaporation, which latter would be very considerable from so extensive a surface of water under the influence of the powerful summer sun of this country. I cannot consider it safe to depend on so inadequate a supply for keeping up the necessary demand for a large canal.

19. With reference to the second method of acquiring head-water for a canal, it must be borne in mind that a reservoir should always be subject to two conditions: first, it ought in itself to be sufficiently low to collect flood waters from an ample surface of country; and secondly, so high as to enable the whole of the water in it being drawn into the summit level of the canal.

20. The position of the Scadouk River is such as not to comply with the first of the two conditions stated, because there is not elevation of land sufficient to afford an ample surface from which to collect flood waters under ordinary circumstances; it is only under the extraordinary cases of freshets that reliance could be placed for an adequate supply. These influences are not of long continuance, and vary in quantity according to the quantity of snow that may fall during the winter, and the extent of the rains which usually occur at the breaking up of that season: the questions therefore that naturally arise are,—can a sufficient quantity of water be collected during the freshets to furnish the requisite supply for the working season? and, can that supply be made available?

21. An accurate survey, and sections taken of the ground surrounding the reservoir proposed, can alone determine the extent to which the waters might be raised in answer to the first question; and the second question can only be answered by ascertaining if the relative positions of the canal and reservoir are in accordance with the second condition stated in paragraph 19, or can be made so. To make them comply effectually with the condition, viz., that the reservoir shall be so high that the whole of the water may be drawn into the summit level of the canal, it will be necessary to find a route so

much lower than the marsh which would form the bottom of the reservoir, that these marshes shall be on a level or rather above the surface water of the canal.

22. The only probability of obtaining such a result appears to be, to endeavour to find a route which will admit of carrying the canal so much below the point O, as to render the whole of the water in the reservoir available: judging, however, from the appearance of the surrounding country, I do not think such a route can be obtained without an enormous quantity of excavation, and at the expense of lengthening the canal several miles. An exploration might be made with this view, should it meet your Excellency's wishes, but I am by no means sanguine in my expectations of any favourable result.

23. The practicability of forming a canal on this route hinges entirely on the possibility of obtaining an adequate supply of water on the summit level. However advantageous other parts of the line may prove, either in respect to the supply of water, or general level of the ground, they cannot be made use of until the summit level be perfected. It may appear, therefore, almost superfluous to discuss their merits now; but as it may be satisfactory to your Excellency to be put in possession of such facts regarding them as I may be able to produce, I proceed to state, that the Memramcook River, from the place where I crossed it, to the mill, shown on Plan No. 2, is a succession of rapids, very shallow, being in many places not more than 1 foot deep, the bottom sandstone rock, which forms the substratum of nearly the whole ground over which I passed. At the mill the dam might be raised considerably higher than it is at present; by raising it, however, a great deal of fine alluvial land would be overflowed and destroyed. The tide flows to the mill, below which the river winds through low and almost level marshes to Dorchester Island.

24. The great winding of the river renders it very exceptionable for the purpose of navigation; and any measures to straighten it would tend to increase the already very rapid tide. It would be preferable to cut the canal the whole way, or nearly so, from the mill to Dorchester Island, to making use of the river; but as it is not advisable to admit the tidal waters of the Bay of Fundy, for reasons before stated, such a measure would very much increase the demand for fresh water to maintain so great a length of canal.

25. Independent of the deficiency of water on this route, there would necessarily be a great amount of lockage, and a distance of nearly half a mile to carry the canal into Shediac Harbour, to insure a proper depth of water, both of which would add very materially to the expense.

26. The ordinary flood tides in Shediac Harbour are from 1½ to 2½ feet; the spring tides rise 4 feet. It is a singular fact, that in Shediac Harbour the tide ebbs to the ordinary low-water mark once only in 24 hours.

27. The third and last route examined by me, was from Shediac Harbour to the bend of the Peticodiac River, 15½ miles. Having previously passed over the ground between

these two points, I at once perceived that the only dependence to be placed for water on the summit level, was in the mill-pond shown in Plan No. 3. Under these circumstances it was scarcely worth the trouble of minute examination; nevertheless, in justice to the public, I directed my course toward the mill-pond, and thence continued it until I debouched on Babineau's Marsh, 2 miles below the settlement called the Bend. I selected this marsh because it appeared favourable to the formation of a basin to hold vessels waiting for an exit into the Peticodiac River.

Plate LVIII. Plan No. 3.

28. The ground passed over, shown by a dotted line on Plan No. 3, is considerably more elevated than that of either of the other routes, and I found that the mill-pond is 119 feet 4·8 inches higher than the neap flood tide in Shediac Harbour, and 113 feet 6·6 inches above the corresponding tide in the Peticodiac River. I think it probable that a more level course than that I adopted might be found between the two points, but not without passing over an elevation equal to that which the mill-pond possesses; but in the absence of a more liberal supply of head-water than could be afforded by the mill-pond, it is scarcely advisable to expend time and money in the search.

29. It will require an inspection only of the Plan No. 3 and accompanying section, to show the impracticability of carrying a canal by this route; but admitting a more level line might be found to the mill-pond, and even that a canal might be formed whose surface water would be 20 feet lower than that of the mill-pond, it would require nineteen locks of 10-feet lift each, to pass over the elevation, which, with a regulating lock at each end, would make twenty-one locks necessary; the expense of each of which would not be reckoned at less than £10,000. The cost of lockage alone would therefore amount to £210,000.

30. I may observe that the access to a canal on this route would be attended with considerable difficulty and expense: on one side is the very shoal water in Shediac Harbour, to overcome which, would require the canal to be carried nearly a mile into the sea,—a work which could not be executed without resorting to the use of expensive coffer-dams, or of the diving bell; on the other hand are 18 miles of the Peticodiac River by no means of easy navigation, although I am informed that vessels in the hands of skilful pilots rarely meet with an accident.

31. It is only in a case when the requisite supply of water, and other favourable circumstances, render the practicability of carrying such a project, as has been suggested, successfully into operation, that the entering upon the undertaking, which must necessarily involve great expense, is justifiable: I cannot consider it so in the present instance. If I am in error, I have erred on the side of caution; and much as I shall regret that my opinion may overthrow what has long been a favourite project in this province, I consider from what I have observed upon the examination of the several routes, that the deficiency of head-water renders the construction of a canal of the ordinary description impracticable.

32. The most natural position for a channel of communication between the Bay of

Fundy and the Gulf of St. Lawrence is evidently from the head of Cumberland Basin to Bay Verte; and since it is not advisable to attempt to construct a canal of the ordinary description, for the reasons above stated, it may be worth while to consider what would be the effect of cutting a channel from water to water, leaving it to the waters themselves to complete the communication to render it navigable. The level of the neap flood tide at Tignish River is 9 feet ½ inch lower than the corresponding tide in the Tantamar River; at flood tide in the latter the water would flow into Bay Verte, and so soon as the tide ebbed below the corresponding tide in Tignish River, which it would do because it ebbs so much more in Cumberland Basin than in Bay Verte, the waters of the latter would flow into the former, and would, on account of the great ebb in the Bay of Fundy, continue to flow much longer than it would the other way. The prevailing water, therefore, flowing through the channel, would be the clear water of the Gulf of St. Lawrence, and would counteract any ill effects that might arise from the muddy waters of the Bay of Fundy. The subject would, however, be much more advantageously considered when Captain Owen, R. N., has completed the tidal observations contemplated by him in the course of his survey of the Bay of Fundy. In the mean time, should it meet your Excellency's wishes, I might in the ensuing summer make a further examination of the ground between the two waters, so as to ascertain the best line on which such a channel might be formed, with a view to the least amount of excavation, and the most advantageous points of connection with the Bay of Fundy and the Gulf of St. Lawrence.

I have the honour to be,
Your Excellency's most obedient humble servant,
H. O. Crawley,
Captain, Royal Engineers.

Fredericton, January 19, 1843.

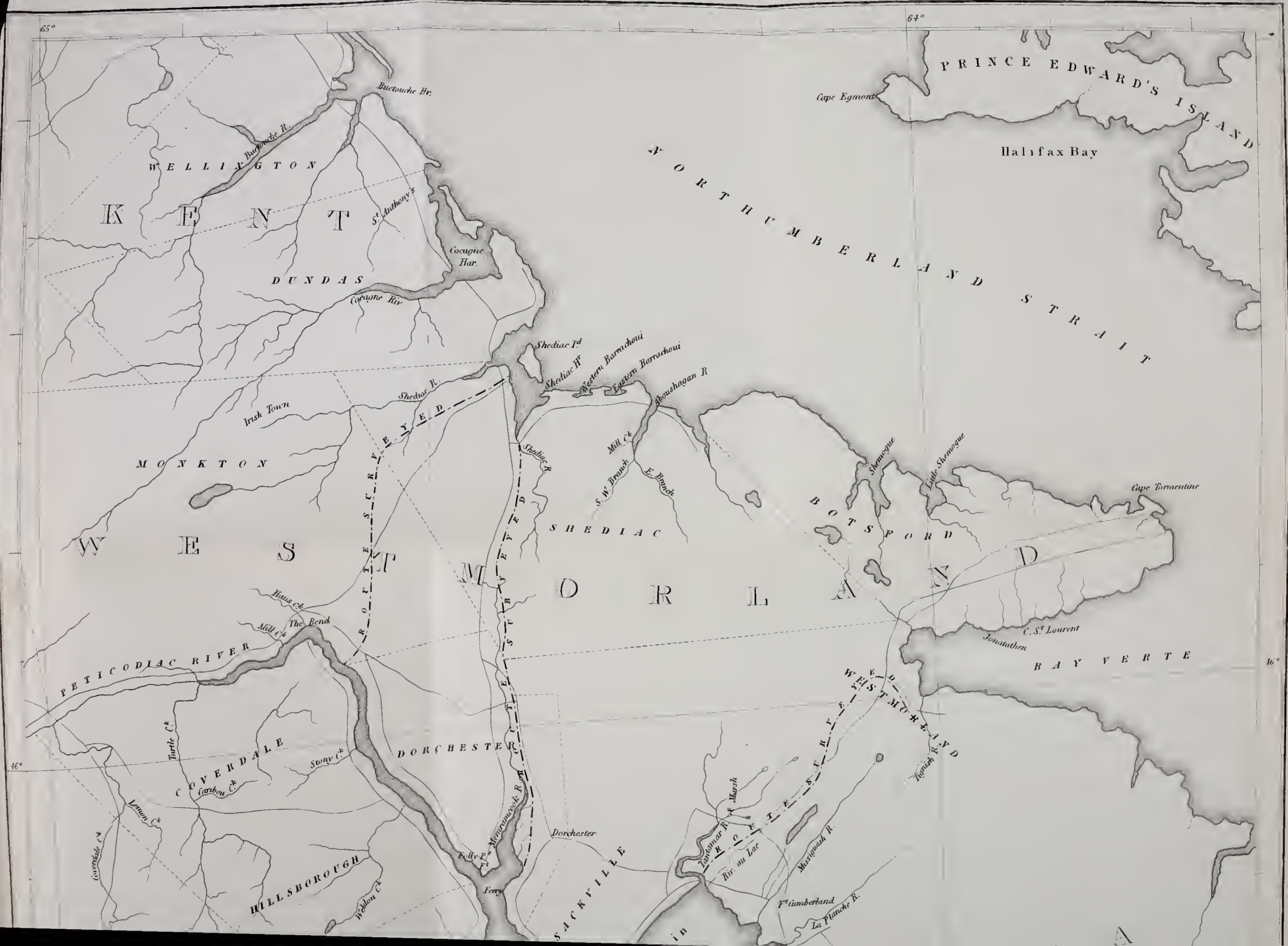
Fredericton, N. B., 9th March, 1843.

May it please your Excellency,

1. In reference to the concluding paragraph of my Report on the survey of a line for a canal to unite the Bay of Fundy with the Gulf of St. Lawrence, I have the honour to offer the following observations on the practicability of cutting a channel across the isthmus connecting New Brunswick with Nova Scotia.

2. The object in view is, to cut a channel of moderate dimensions from Bay Verte to Cumberland Basin, and to permit the action of the waters, thus united, to form a channel sufficient for the purposes of navigation.

3. The tidal observations which are about to be made by Captain Owen, R. N., I am given to understand, will not be completed in less than one year from the time of commencing them. In the absence of the result of these observations, I cannot give any


65°
64°
PRINCE EDWARD'S ISLAND
Cape Egmont
Halifax Bay
NORTHUMBERLAND STRAIT
Buctouche Hr.
Buctouche R.
WELLINGTON
KENT
St. Anthony's
Cocagne Har.
DUNDAS
Cocagne Riv.
Shediac Id
Shediac Hr
Western Barrachoui
Eastern Barrachoui
Aboushagan R.
Shediac R.
Irish Town
MONKTON
ROUTE SURVEYED
Shediac R.
Mill Ck
S. W. Branch
E. Branch
SHEDIAC
Shemogue
Little Shemogue
Cape Tormentine
BOTSFORD
WESTMORLAND
Haus Ck
The Bend
Mill Ck
PETICODIAC RIVER
ROUTE SURVEYED
C. St. Lourent
Jonatathen
BAY VERTE
46°
WESTMORLAND
ROUTE SURVEYED
Turtle Ck
COVERDALE
Caribou Ck
Stony Ck
DORCHESTER
Tignish R.
46°
Lemon Ck
Coverdale Ck
Memramcook R.
Folly Pt
Ft
Dorchester
Marsh
Tantamar R.
Riv. au Lac
Missiguash R.
HILLSBOROUGH
Weldon Ck
Ferry
SACKVILLE
Ft Cumberland
La Planche R.
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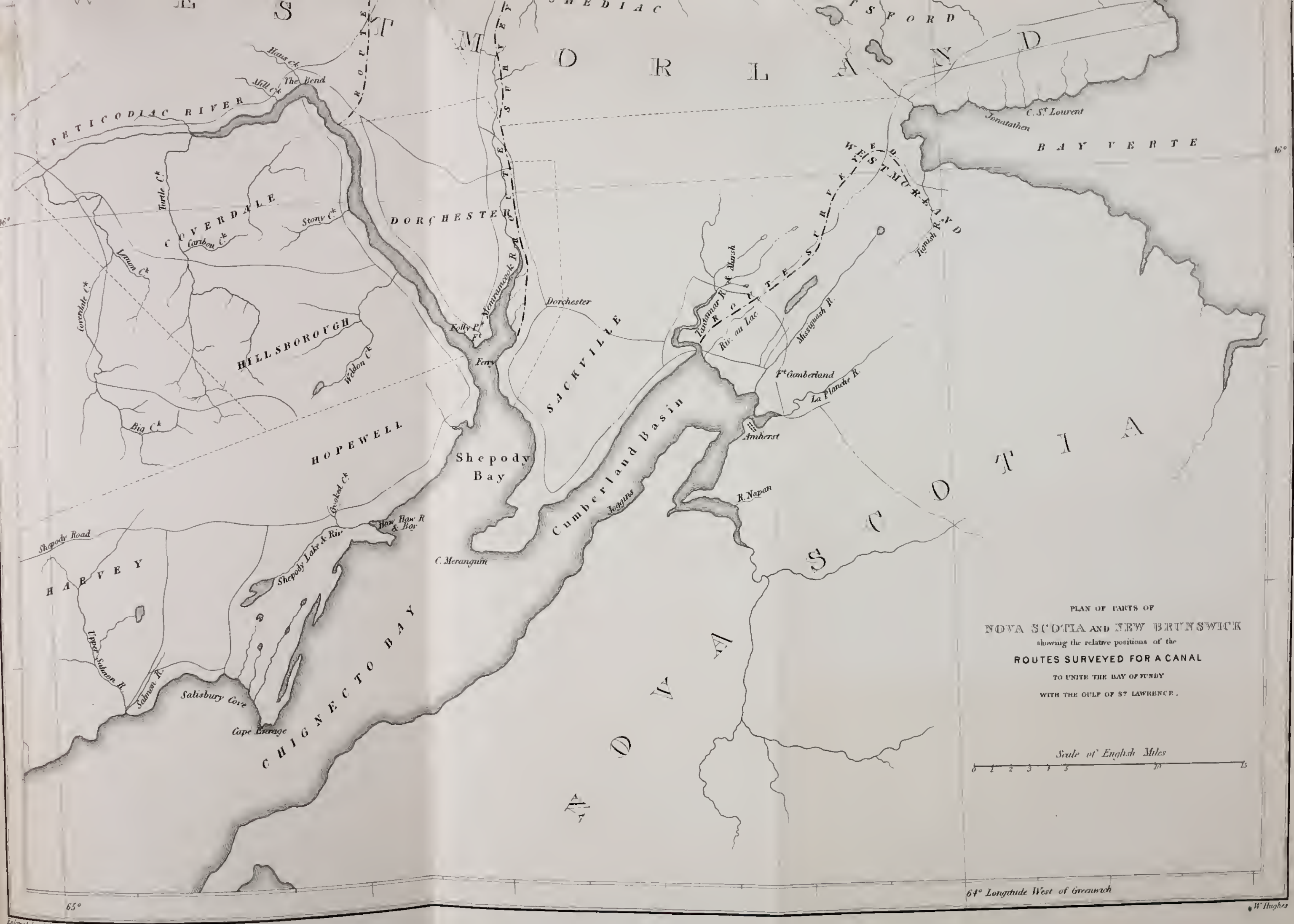
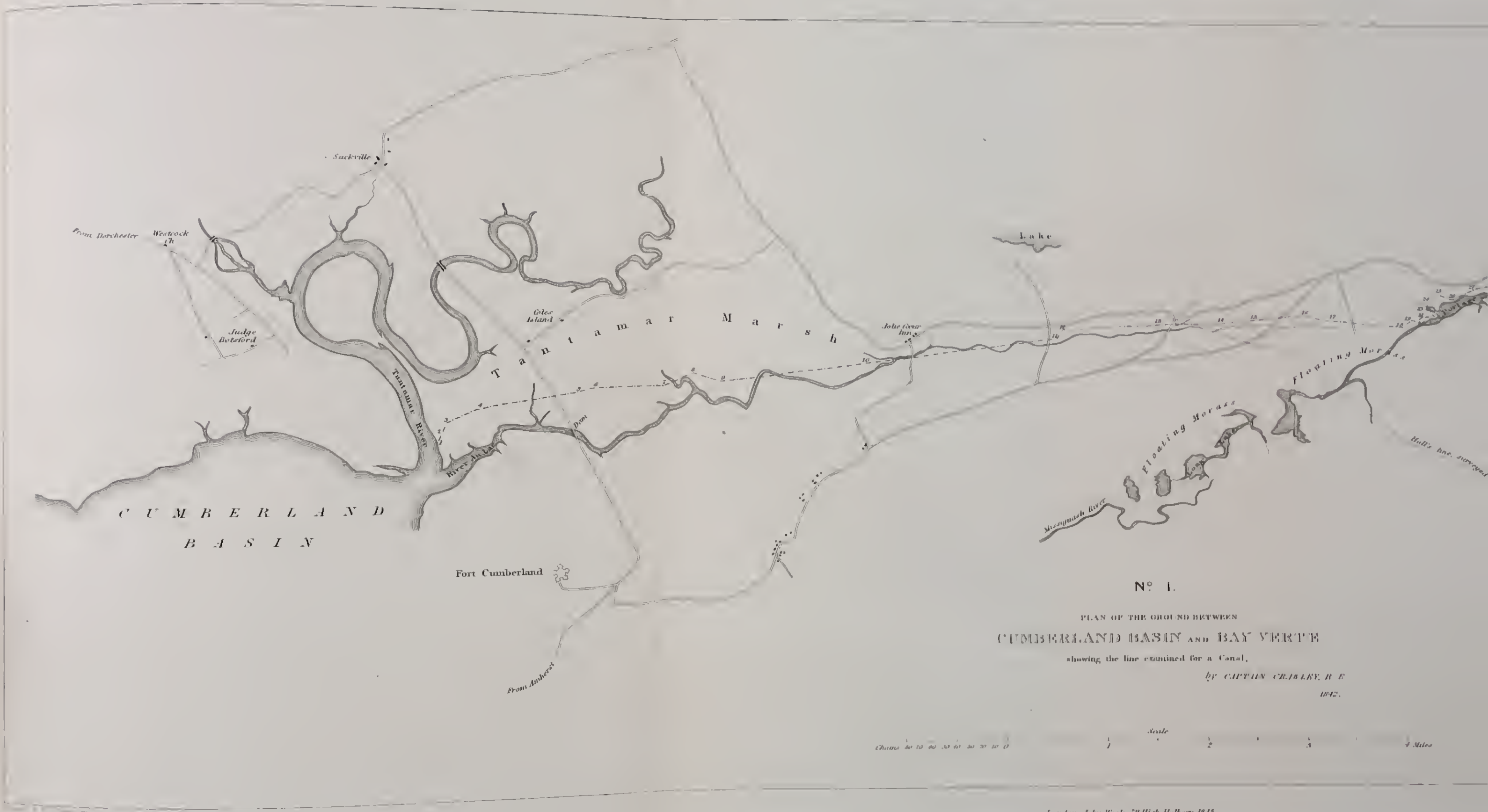


PLAN OF PARTS OF
NOVA SCOTIA AND NEW BRUNSWICK
showing the relative positions of the
ROUTES SURVEYED FOR A CANAL
TO UNITE THE BAY OF FUNDY
WITH THE GULF OF ST LAWRENCE.

Enlarged by G.D. Dempsey

London John Weale 59, High Holborn, 1845.

W. Hughes



Nº 1.

PLAN OF THE GROUND BETWEEN

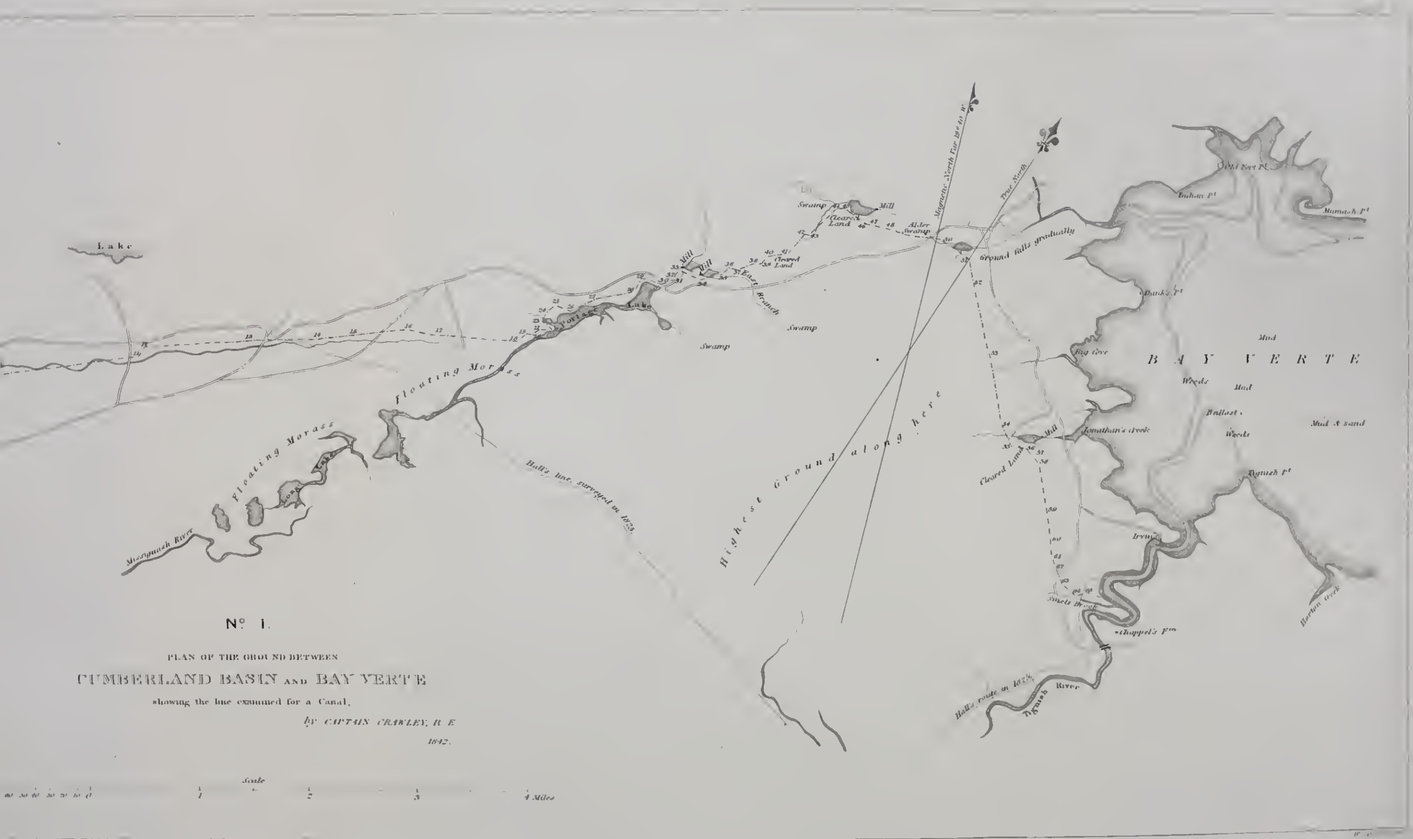
CUMBERLAND BASIN AND BAY VERTE

showing the line examined for a Canal,

by CAPTAIN CRAWLEY, R. E.

1842.

London John Weale, 59 High Holborn 1845.



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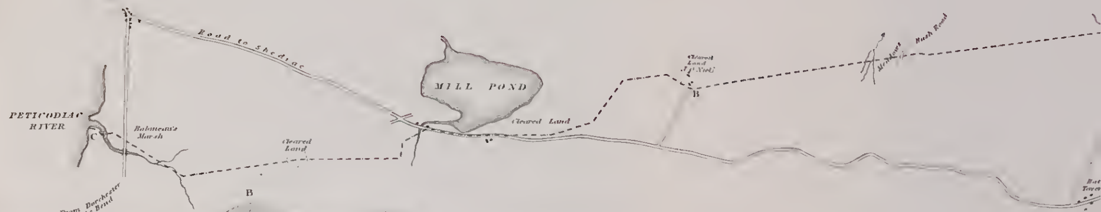
Nº 3.

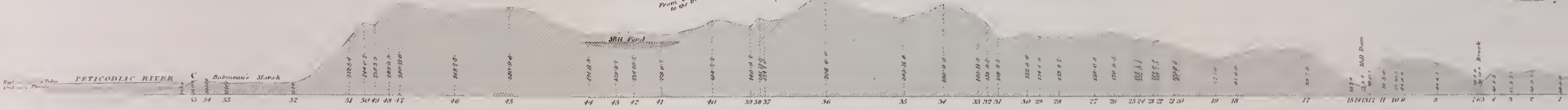
PLAN OF THE GROUND BETWEEN
SHEDIAC HARBOUR AND THE PETICODIAC RIVER

shewing the line examined for a Canal,

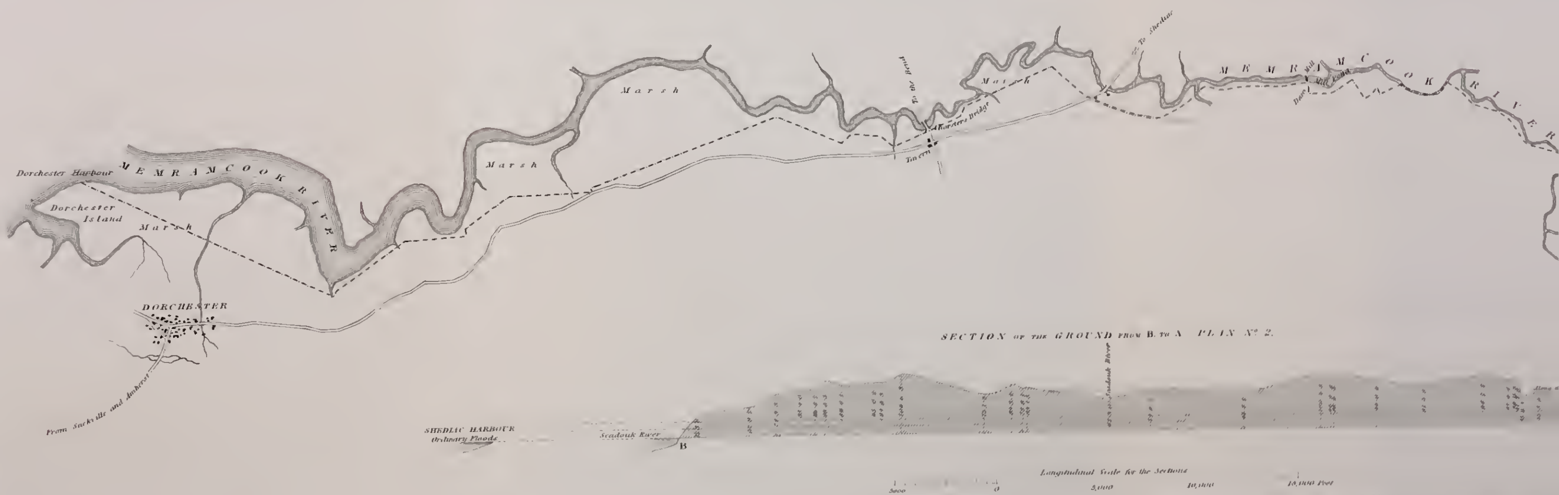
by CAPTAIN CRAWLEY, R.E.

1842.





SECTION OF THE GROUND ON THE LINE MARKED A B C ON THE PLAN Nº 3.

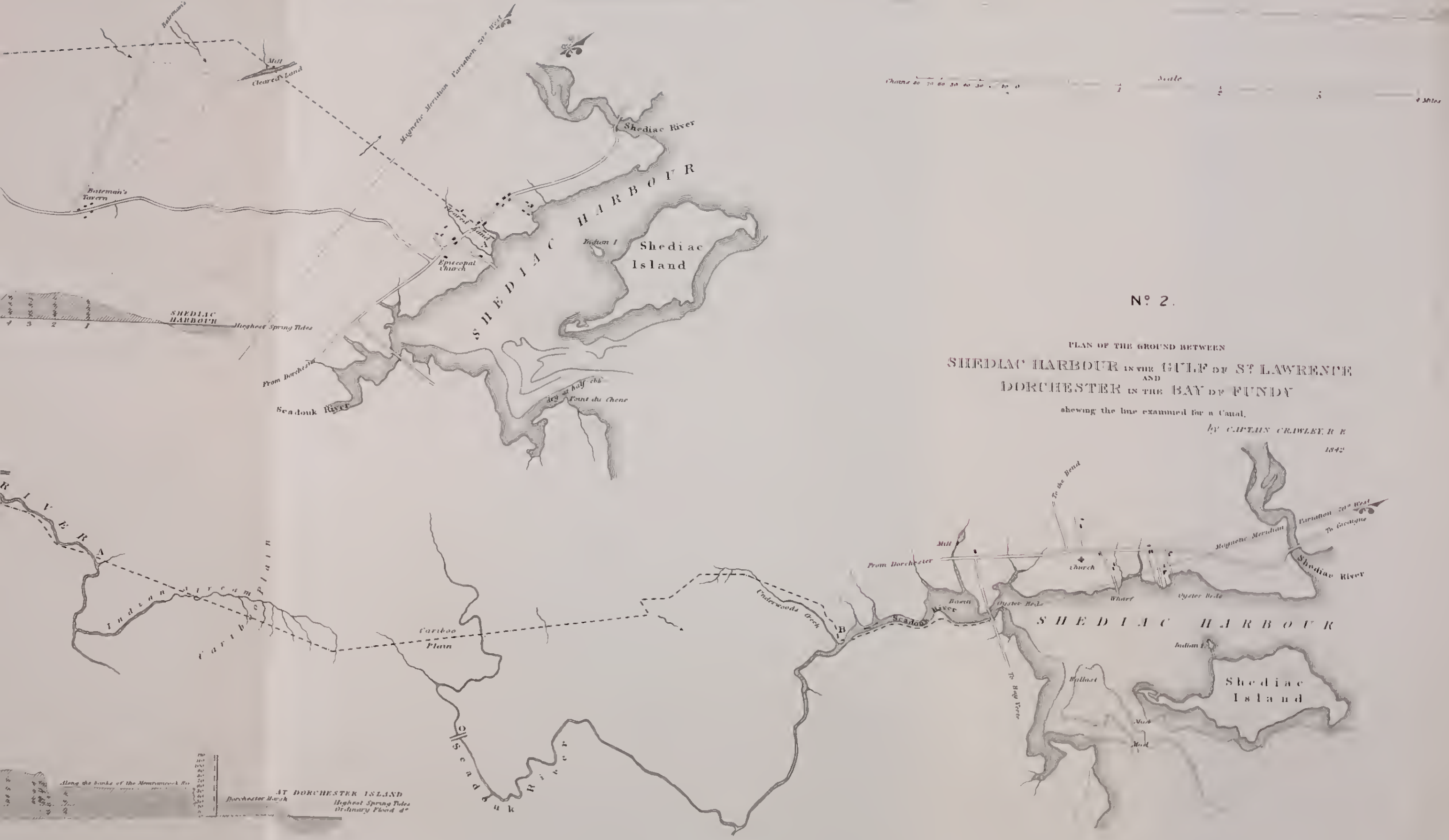


SECTION OF THE GROUND FROM B. TO A PLAN Nº 2.

Longitudinal Scale for the Sections

5000 0 5,000 10,000 15,000 Feet

London. John Weale, 59, High Holborn 1845.



No. 2.

PLAN OF THE GROUND BETWEEN

SHEDIAC HARBOUR IN THE GULF OF ST LAWRENCE
AND
DORCHESTER IN THE BAY OF FUNDY

shewing the line examined for a Canal.

by CAPTAIN CRAWLEY, R.E.

1842

accurate account of the difference of level of the tides, so as to determine the fall from one point to the other, in order to judge if the current will be of sufficient force to effect the desired object; but admitting the fall to be sufficient, it may be well to consider the effect such an opening would have on the Tantamar or adjoining marshes.

4. Every spring tide would, if not restrained by the dikes, flood the marshes, which are the most valuable parts of the farms in that neighbourhood. On opening a channel as proposed, it will be highly important that the safety of these marshes shall not be compromised: to prevent this will be a matter of considerable difficulty.

5. The soft soil of which the marshes are composed would offer so little resistance to a current of water, that it would be difficult to set limits to the width of the channel. Dikes placed at any reasonable distance apart, between which the channel should be formed, would be liable to be undermined and thrown down by the action of the water on the banks,—a circumstance of frequent occurrence to the present dikes, and from which cause the Tantamar River is continually and perceptibly altering its course; and as the depth of the channel would gradually extend to upwards of 40 feet, it would be extremely difficult to secure the banks by piles.

6. That part of the excavation towards Bay Verte would be through sandstone rock, which would yield very little to the action of the water; it would be highly probable that the rocky channel would become, in process of time, a dangerous rapid; and at the junction of the rock with the marsh land, the water, instead of continuing to flow with a gradual slope towards Cumberland Basin, would, on leaving the rocky part, scoop out the soft soil, and form a fall.

7. It may be observed, that the communication would be for some time interrupted between New Brunswick and Nova Scotia, as no bridge could be placed across the channel until the ultimate width of it was determined.

8. These circumstances, deduced from theory, appear to me to render it doubtful after all if a channel, as proposed, would be easily navigable. At all events, so much uncertainty appears to exist, that the project would be extremely hazardous. With this view of the case, your Excellency may probably agree with me, that it is not desirable to prosecute the inquiry further.

I have the honour to be,
Your Excellency's most obedient humble servant,
H. O. Crawley, R. E.

His Excellency Sir W. M. G. Colebrooke, K. H., &c., &c., &c.

XVII.—*Description of the Method of Reclaiming the Tantamar and adjoining Marshes, in New Brunswick, from the Sea. By Captain* H. O. Crawley, *R.E.*

The following description of the method of reclaiming the Tantamar and adjoining marshes, in New Brunswick, from the sea, may be acceptable to some of my Brother Officers.

Cumberland Basin is the most northern part of the Bay of Fundy, forming with Bay Verte, in the Gulf of St. Lawrence, the isthmus connecting Nova Scotia with New Brunswick. The distance from water to water in a direct line is about 15½ miles, full five of which is marsh land reclaimed from the sea by embankments.

The marsh is divided by a ridge of land, on the southern extremity of which stand the remains of Fort Cumberland, originally of French construction, and which was in former days the scene of active warfare.

Through the marsh on the western or New Brunswick side of the ridge of land flow the Tantamar and Au Lac rivers, from the former of which the marsh derives its name.

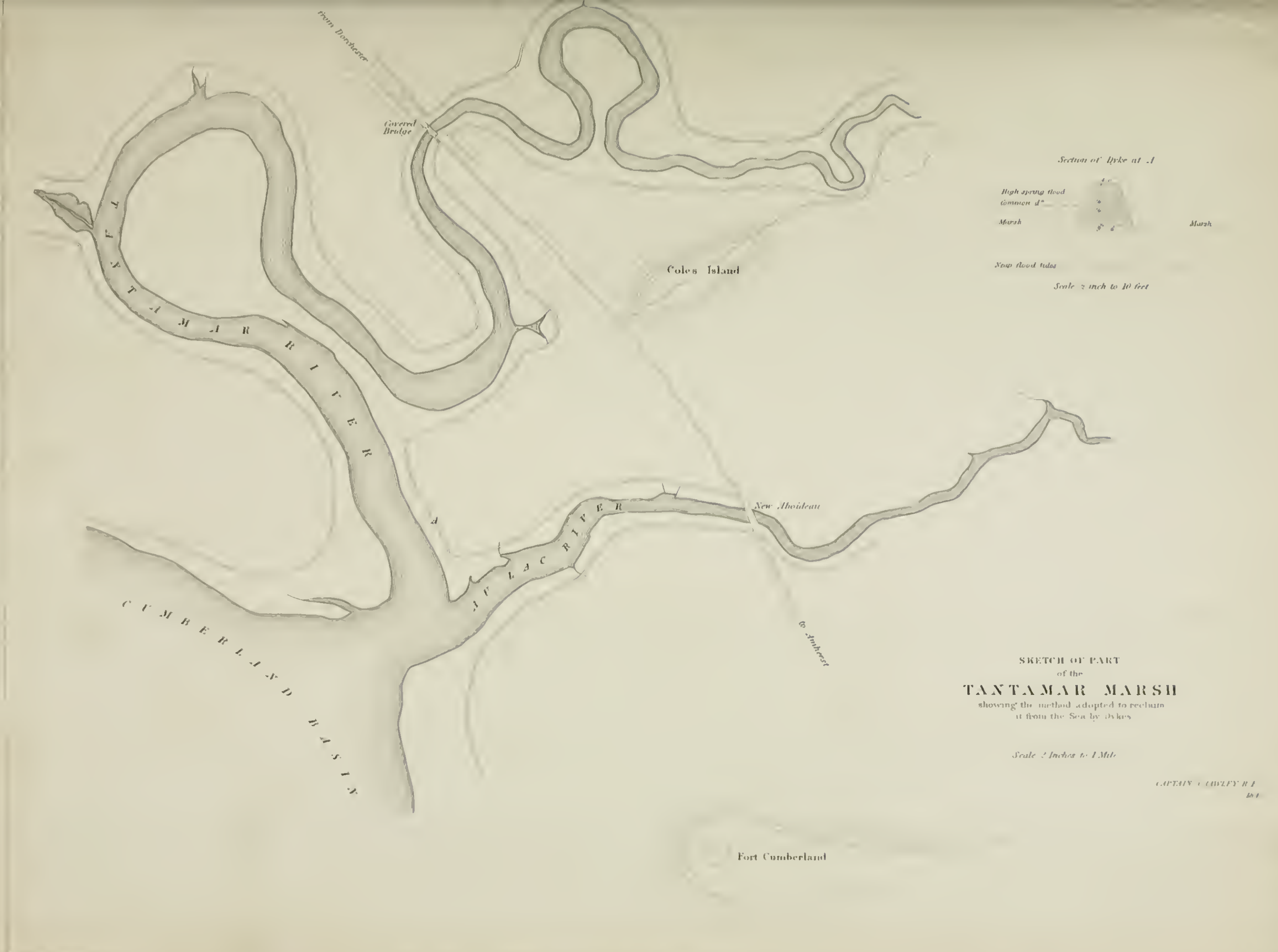
The mode adopted for reclaiming the marsh from the sea, a great part of which has been recently effected, has been as follows:

A bâtardeau, or, as it is locally termed, an aboideau, is formed across the rivers, which are tidal and nearly dry at low water, sufficiently high to prevent the access of the highest spring tides. Embankments or dikes of equal height to the aboideau are then constructed on each side the river and across the marsh, terminating on the high land on either side. The accompanying plan shows the directions of the dikes sufficient to illustrate the method, but is not a correct delineation of the dikes as they exist. Plate LIX.

The surface soil of the marsh, which is clay mixed with roots of grasses, affords good material for the dikes, which are solely composed of it.

In order to drain the marsh above the aboideau, a self-acting sluice is constructed in the latter, which admits of the water running off at low water, and is closed by the action of the water at flood tide.

The aboideau is formed by first driving piles for a foundation; the superstructure is composed of alternate layers of brushwood and clay. As many men as can work are employed night and day to raise the structure above the ordinary flood tides, and as the work settles it is continually added to until the required height and firmness are obtained. I regret that it is not in my power to give a section of this work.



SKETCH OF PART
of the
TANTAMAR MARSH
showing the method adopted to reclaim
it from the Sea by Dykes

Scale 2 Inches to 1 Mile

CAPTAIN COWLEY R.E.
[illegible]

These aboideaux have been formed in several places, commencing some distance above the mouth of the river, gradually reclaiming the marsh, each succeeding aboideau being nearer the sea. The main road from New Brunswick into Nova Scotia traverses the aboideau lately constructed; the old ones are still useful as causeways across the old beds of the rivers, but the dikes connected with them are now obsolete.

The French had formerly commenced an aboideau where the present new one is formed, but were interrupted by the war which drove them from the country. Had that been completed by their successors, much expense would have been saved, and the marsh so much sooner reclaimed.

These marshes are valuable property, yielding, after having been reclaimed two or three years, first an abundant crop of what is provincially termed broad-leaf grass, and subsequently forming excellent meadows, which are there termed English marsh. Large crops of hay are annually secured from the marshes, the production of which is altogether spontaneous, as the farmers do not take the least pains to cultivate, although they confess the crops are less abundant yearly.

Probably if they were occasionally flooded they would be improved, because the waters of the Bay of Fundy, wherever they flow, leave a slimy deposit, to which, after the salt has been diluted, as it were, by the rain and snow of the winter, and has evaporated, the proprietors attribute the great fertility of their marsh lands.

The sluice in the aboideau, and others constructed in the dikes, would effect irrigation, and the inundations could be kept under control.

The draining of the marshes is assisted by wide ditches connected with the beds of the rivers above the aboideaux.

The new aboideau cost £5000 currency.

H. O. Crawley,
Captain, Royal Engineers.

14th March, 1843.

XVIII.—*Description of an Engraved Protractor in use by the United States' Corps of Topographical Engineers.* *By* SAMUEL B. HOWLETT, *Esq., Ordnance.*

IT is desirable that the means of plotting angles should rather be superior than inferior to the means employed to obtain those angles in the field. When a theodolite reading to minutes of a degree is used, the protractor for laying down the angles should not only read to minutes, when the scale is large, but should be of a radius rather greater than that of the theodolite, so as to make sure that nothing of the care taken to obtain accuracy in the survey shall be lost in laying down the work upon paper.

For plotting a survey to a large scale, made with an instrument reading to minutes, I have never met with any protractor or system of plotting more correct, expeditious, and generally convenient, than that described in the book of pattern instruments for the general service of the Ordnance, and also in the first volume of R. E. Professional Papers. But, for plotting work done with a surveying compass, which cannot be depended upon to nearer than half a degree, the book of patterns provides a common circular brass protractor by which an angle may be plotted to a quarter of a degree, thus recognizing the principle that the protractor should be superior in its capability of accuracy to the instrument for taking angles used in the field.

The engraved protractor used by the United States' Corps of Topographical Engineers, and which it is the object of this Paper to make known, is so simple that no more particular description of it is necessary than to mention, that it is a circle 12 inches in diameter, divided to quarter degrees, printed from a copper-plate, in red ink, in the middle of a sheet of drawing paper; and the degrees are not figured. The centre is marked, and the bearings required to be plotted are supposed to be transferred to the stations by a 12 or 15-inch rolling parallel ruler.

One of these sheets has lately been submitted to the Inspector-General of Fortifications in a letter from Lieut. Simmons, Royal Engineers, and the General having recommended that this protractor shall be adopted in the Ordnance Department, the Board have ordered a plate to be prepared, and copies kept ready to meet demands from the stations.

The sheets on which these protractors for the general service of the Ordnance are printed, measure 24 by 19 inches; and in order to avoid the margin produced by the pressure of a plate, when it is less than the paper, the plate is the full size, giving to the whole sheet a smooth surface.

As no common engraver has the means of dividing such a circle on a plate in a proper manner, the plate was engraved by that beautiful piece of mechanism, the dividing engine lately constructed by Messrs. Troughton and Simms, so that the plate itself is divided as perfectly as an astronomical instrument; and after inspecting numerous sheets, by placing a straight edge across the centre and opposite divisions, in several parts, I found that no unequal contraction of the paper in drying had happened sufficient to cause any error that could be detected.

Though this system of plotting a survey is not equal, when great accuracy is necessary, to that first adverted to, it certainly must be regarded as greatly superior for most purposes, to the method in which either the circular brass protractor, or the much used card-board protractor, is employed.

The 12-inch card-board protractors have the middle part cut out, and if the work will not come in within that space, they must be shifted to another meridian on the paper; and there is an awkwardness in having the thickness of the card-board between the parallel ruler and the paper on which the station lines have to be drawn. The brass circular protractor requires that all the angles shall be first pricked off and numbered, and the protractor removed, before the parallel ruler can be set to transfer the bearings one after the other to their respective stations; with the disadvantages of the radius being short, and having to put it afresh on the meridian if more angles are required to be pricked off. But, by the present method, all these causes of mistake are avoided.

In using this protractor, the first thing to consider is, in what direction the working meridian should be chosen so as to bring the work on the paper; and the zero being thus determined, the principal divisions may then be numbered in pencil, so as to suit the figuring of the instrument with which the survey was made, whether to four times 90°, to twice 180°, or to 360°.

When the plotting of the station lines shall have been pricked off on the fair plan, the pencil lines may be removed, and the sheet used again many times; or, as the impression is only in faint red, it might be desirable, for some purposes, that the survey should be finished on the same sheet, in which case the zero would be marked as the magnetic north, and the true meridian drawn.

Looking at the manner in which the boundaries of lands are usually described in the Colonies, I should think these protracting sheets would be very useful in preparing the surveys. A piece of land, for example, is thus described: "North sixty-five degrees east, four chains and eleven links; south twenty-one degrees thirty minutes east, five chains and twenty-seven links; south seventy degrees thirty minutes west, three chains and eighty links; and north twenty-five degrees west, four chains and eighty-five links, to the place of commencement." In the margin of the deed there is a diagram of this four-sided piece, with all these particulars written against the respective boundaries, the first line being put N. 65°, E. 411°.

But if this same piece were surveyed with an instrument reading to 360°, the relative bearings of the boundaries would be simply recorded as 65°, 158° 30′, 250° 30′, and 335°, respectively without reference to the points of the compass, except that the zero should denote the magnetic north.

It was to meet both these methods that the brass circular protractor was figured as shown in Plate IV. of the book of pattern instruments, having on the outside edge the degrees figured from right to left to 360°; and on the inner space the degrees figured to 90° on each side of north, and in like manner on each side of south.

But, considering the diversity of habits and opinions, it is no small advantage of the present simple protractor that it imposes no restriction, as the degrees may be figured just as required; and there can be no difference of opinion as to the advantages of the sheets being cheap, and convenient for travelling.

83½, Pall Mall,
20th August, 1845.

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THE FIRST SEVEN VOLUMES.

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THE FIRST SEVEN VOLUMES.

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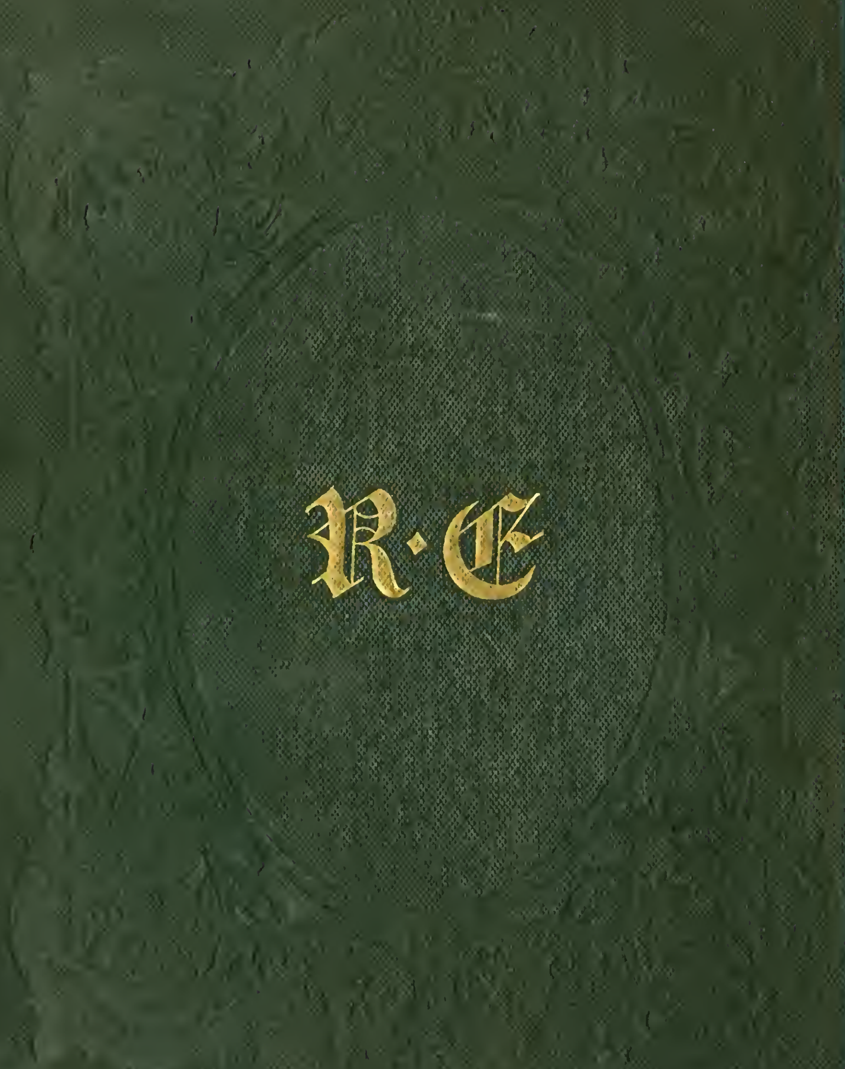
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